1. THE EYE AS A CAMERA

The historical perspective

Pythagorus (BC 582–500) and his followers believed that sight was akin to the sense of touch and that light travelled outwards from the eye to 'touch' objects in order for us to see them. They thought that there was 'fire' within the eye and the Pythagorean, Theophrastus (BC 372 – 286), justified this view by observing that 'when one is struck, [the inner fire] flashes out'. Plato (BC 428 – 348) believed that the internal fire and daylight came together in a special way to enable us to see. Aristotle (BC 384–322), on the other hand, rejected the idea of light emissions from the eye and felt that air was the necessary medium to complete the touching.

There was considerable confusion in this area until the time of the great Arab physician, Alhazen or Ibn Al-Haithen (935 – 1039), who surmised that rays of light came from objects to the eye. Because of a misunderstanding of his terminology, it was once believed that Alhazen thought that the image we see formed on the interior back surface of the lens. More recently, it has been realised that he was probably aware of the fact that the image formed on the interior back surface of the eye itself (001). The earliest known detailed diagram of the eye also came from Arab sources: the 9th century manuscript of Ibn Ishaq titled, 'Book of the Ten Treatises on the Eye' (002).

It was not until 1604 that Kepler (1571-1630), brought together the then current knowledge of optics, light and the anatomy of the eye sufficiently to explain vision more or less in the terms that we know it today (003). He saw the eye as an object similar to a camera or, rather, to a camera obscura, although this notion had been put forward earlier by both Alhazen and Leonardo Da Vinci (1452–1519). It is possible that Leonardo knew of Alhazen's work, although this was not translated into Latin by Vitello until 1572 under the title: 'Opticae thesaurus Alhazeni arabis libri septum'. For some reason though, Leonardo could not accept that the image falling onto the rear of the eye would be upside down (as he saw it to be in the camera obscura). His model of the behaviour of light in the eye was governed by his need to postulate an upright image. Kepler had a more correct
view and also realised that an understanding the mechanisms of the eyes alone was insufficient to explain the phenomenon of vision. He was, however, happy to leave this further explanation to the 'natural philosophers' and was untroubled by the fact that the retinal image was upside down. He suggested that we perceive the image to be the right way up because of the 'activity of Soul' or, as we would now put it, through 'mental processes'. Even today, although we now understand much about the anatomy and mechanisms of the eyes and brain, we are far from having a complete picture of the processes of perception. Those interested in pursuing the historical aspects of the subject will find Crombie (004) and Lindberg (005) of considerable value.

Physical aspects

From the physical point of view, Kepler's camera analogy is a reasonably accurate one, as Wald (006) confirms. The eye is a more or less light-tight, roughly spherical chamber about 26 mm across with a lens system at the front and a light-sensitive surface, the retina, at the back. The lens system serves to focus an image onto the retina in the way that a camera lens focusses an image onto photographic film. Unlike a camera, though, where focussing is achieved by moving the position of the lens relative to the film, the eye focusses by changing the shape of its lens.

Something like a camera, too, the human eye is lined with a dark, almost black, matt surface to prevent too much back-scattering of light. This is called the choroid membrane. It is interesting to note that not all animals' eyes have this dark lining. On the contrary, the eyes of animals of nocturnal habit, cats for instance, have a shiny lining which reflects incident light back into the eye, presumably to improve its light-gathering properties - inevitably with considerable reduction in sharpness. The presence of this reflecting surface, called the tapetum, is the reason that cats' eyes seem to glow in the dark and might have contributed to the early notions of the eyes sending out beams. (It is worth noting here that, as only macaque monkeys have eyes which closely resemble human eyes, we must generally beware of extrapolating any concepts about animal vision to humans).

Our retinas incorporate two types of light-sensitive cells: rods - which deal with low light conditions; and cones - which deal with normal light and colour. The rods and cones - so named because of their shapes - are connected in bundles to the optic nerve which channels the signals they produce to the brain for interpretation. In each eye there are about 130 million rods and cones but these are not distributed equally over the whole retina and rods outnumber cones by about 17 to 1. The majority of the cones are concentrated in one tiny, slightly depressed spot, no larger than the head of a pin, where there are no rods at all. This feature is known as the fovea, (Latin for 'pit'), and in order to see anything really clearly, we must direct its