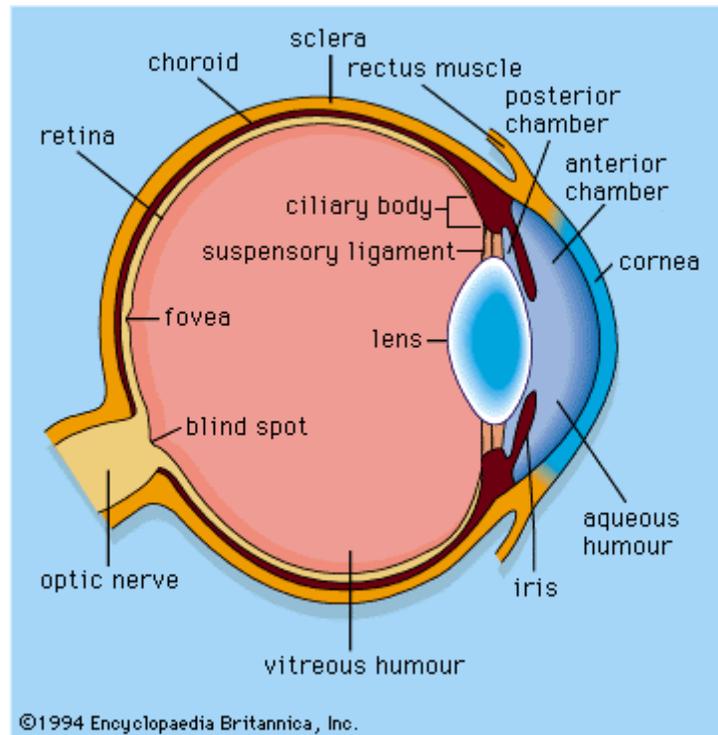


Some Readings about the Eye

Introduction



The general mammalian eye

Sensory Reception

The inner tunic of the globe.

The inner tunic of the rear portion of the globe, as far forward as the ciliary body, is the retina, including its epithelia or coverings. These epithelia continue forward to line the remainder of the globe.

The epithelia.

Separating the choroid (the middle tunic of the globe) from the retina proper is a layer of pigmented cells, the pigment epithelium of the retina; this acts as a restraining barrier to the indiscriminate diffusion of material from the blood in the choroid to the retina. The retina ends at the ora

serrata, where the ciliary body begins (Figure 10). The pigment epithelium continues forward as a pigmented layer of cells covering the ciliary body; farther forward still, the epithelium covers the posterior surface of the iris and provides the cells that constitute the dilator muscle of this diaphragm. Next to the pigment epithelium of the retina is the neuroepithelium, or rods and cones (see below). Their continuation forward is represented by a second layer of epithelial cells covering the ciliary body, so that by the ciliary epithelium is meant the two layers of cells that are the embryological equivalent of the retinal pigment epithelium and the receptor layer (rods and cones) of the retina. This unpigmented layer of the ciliary epithelium is continued forward over the back of the iris, where it acquires pigment and is called the posterior iris epithelium.

The retina.

The retina is the part of the eye that receives the light and converts it into chemical energy. The chemical energy activates nerves that conduct the messages out of the eye into the higher regions of the brain. The retina is a complex nervous structure, being, in essence, an outgrowth of the forebrain.

Ten layers of cells in the retina can be seen microscopically. In general, there are four main layers: (1) Next to the choroid is the pigment epithelium, already mentioned. (2) Beneath the epithelium is the layer of rods and cones, the light-sensitive cells. The changes induced in the rods and cones by light are transmitted to (3) a layer of neurons (nerve cells) called the bipolar cells, which are analogous to the sensory neurons that carry messages from the touch and heat receptors of the skin and transmit them to the cells of the spinal cord or the medulla (the part of the brain that is a continuation of the spinal cord). These bipolar cells connect with (4) the innermost layer of neurons, the ganglion cells; and the transmitted messages are carried out of the eye along their projections, or axons, which constitute the optic nerve fibres. Thus, the optic nerve is really a central tract, rather than a nerve, connecting two regions of the nervous system, namely, the layer of bipolar cells, and the cells of the lateral geniculate body, the latter being a visual relay station in the diencephalon (the rear portion of the forebrain).

The arrangement of the retinal cells in an orderly manner gives rise to the outer nuclear layer, containing the nuclei of the rods and cones; the inner nuclear layer, containing the nuclei and perikarya (main cell bodies outside the nucleus) of the bipolar cells, and the ganglion cell layer, containing the corresponding structures of the ganglion cells. The plexiform layers are regions in which the neurons make their interconnections. Thus, the outer plexiform layer contains the rod and cone projections terminating as the rod spherule and cone pedicle; these make connections with the dendritic processes of the bipolar cells, so that changes produced by light in the rods and cones are transmitted by way of these connections to the bipolar cells. (The dendritic process of a nerve cell is the projection that receives nerve impulses to the cell; the axon is the projection that carries impulses from the cell.) In the inner plexiform layer are the axons of the bipolar cells and the dendritic processes of the ganglion and amacrine cells (see below). The association is such as to allow messages in the bipolar cells to be transmitted to the ganglion cells, the messages then passing out along the axons of the ganglion cells as optic nerve messages.

The photosensitive cells are, in the human and in most vertebrate retinas, of two kinds, called rods and cones, the rods being usually much thinner than the cones but both being built up on the same plan. The light-sensitive pigment is contained in the outer segment, which rests on the pigment epithelium. Through the other end, called the synaptic body, effects of light are transmitted to the bipolar and horizontal cells. When examined in the electron microscope, the outer segments of the rods and cones are seen to be composed of stacks of disks, apparently made by the infolding of the limiting membrane surrounding the outer segment; the visual pigment, located on the surfaces of these disks, is thus spread over a very wide area, and this contributes to the efficiency with which light is absorbed by the visual cell.

The arrangement of the retina makes it necessary for light to pass through the layers not sensitive to light first before it reaches the light-sensitive rods and cones. The optical disadvantages of this arrangement are largely overcome by the development of the fovea centralis, a localized region of the retina, close to the optic axis of the eye, where the inner layers of the retina are absent. The result is a depression, the foveal pit, where light

has an almost unrestricted passage to the light-sensitive cells. It is essentially this region of the retina that is employed for accurate vision, the eyes being directed toward the objects of regard so that their images fall in this restricted region. If the object of interest is large, so as to subtend a large angle, then the eye must move rapidly from region to region so as to bring their images successively onto the fovea; this is typically seen during reading. In the central region of the fovea there are cones exclusively; toward its edges, rods also occur, and as successive zones are reached the proportion of rods increases while the absolute density of packing of the receptors tends to decrease. Thus, the central fovea is characterized by an exclusive population of very densely packed cones; here, also, the cones are very thin and in form very similar to rods. The region surrounding the fovea is called the parafovea; it stretches about 1,250 microns from the centre of the fovea, and it is here that the highest density of rods occurs. Surrounding the parafovea, in turn, is the perifovea, its outermost edge being 2,750 microns from the centre of the fovea; here the density of cones is still further diminished, the number being only 12 per hundred microns compared with 50 per hundred microns in the most central region of the fovea. In the whole human retina there are said to be about 7,000,000 cones and from 75,000,000 to 150,000,000 rods.

The fovea is sometimes referred to as the macula lutea ("yellow spot"); actually this term defines a rather vague area, characterized by the presence of a yellow pigment in the nervous layers, stretching over the whole central retina; i.e., the fovea, parafovea, and perifovea.

The blind spot in the retina corresponds to the optic papilla, the region on the nasal side of the retina through which the optic nerve fibres pass out of the eye.

Although the rods and cones may be said to form a mosaic, the retina is not organized in a simple mosaic fashion in the sense that each rod or cone is connected to a single bipolar cell that itself is connected to a single ganglion cell. There are only about 1,000,000 optic nerve fibres, while there are at least 150,000,000 receptors, so that there must be considerable convergence of receptors on the optic pathway. This means that there will be considerable mixing of messages. Furthermore, the

retina contains additional nerve cells besides the bipolar and ganglion cells; these, the horizontal and amacrine cells, operate in the horizontal direction, allowing one area of the retina to influence the activity of another. In this way, for example, the messages from one part of the retina may be suppressed by a visual stimulus falling on another, an important element in the total of messages sent to the higher regions of the brain. Finally, it has been argued that some messages may be running the opposite way; they are called centrifugal and would allow one layer of the retina to affect another, or higher regions of the brain to control the responses of the retinal neurons. In primates the existence of these centrifugal fibres has been finally disproved, but in such lower vertebrates as the pigeon, their existence is quite certain.

The pathway of the retinal messages through the brain is described later in this article; it is sufficient to state here that most of the optic nerve fibres in primates carry their messages to the lateral geniculate body, a relay station specifically concerned with vision. Some of the fibres separate from the main stream and run to a midbrain centre called the pretectal nucleus, which is a relay centre for pupillary responses to light.

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The transparent media.

Within the cavities enclosed by the three layers of the globe described above there are the aqueous humour in the anterior and posterior chambers; the crystalline lens behind the iris; and the vitreous body, which fills the large cavity behind the lens and iris (Figure 10).

The aqueous humour.

The aqueous humour is a clear colourless fluid with a chemical composition rather similar to that of blood plasma (the blood exclusive of its cells) but lacking the high protein content of the latter. Its main function is to keep the globe reasonably firm. It is secreted continuously by the ciliary body into the posterior chamber, and flows as a gentle stream through the pupil into the anterior chamber, from which it is drained by

way of a channel at the limbus; that is, the juncture of the cornea and the sclera. This channel, the canal of Schlemm, encircles the cornea and connects by small connector channels to the blood vessels buried in the sclera and forming the intrascleral plexus or network. From this plexus the blood, containing the aqueous humour, passes into more superficial vessels; it finally leaves the eye in the anterior ciliary veins. The wall of the canal that faces the aqueous humour is very delicate and allows the fluid to percolate through by virtue of the relatively high pressure of the fluid within the eye. Obstruction of this exit, for example, if the iris is pushed forward to cover the wall of the canal, causes a sharp rise in the pressure within the eye, a condition that is known as glaucoma. Often the obstruction is not obvious, but is caused perhaps by a hardening of the tissue just adjacent to the wall of the canal--the trabecular meshwork, in which case the rise of pressure is more gradual and insidious. Ultimately the abnormal pressure damages the retina and causes a variable degree of blindness. The normal intraocular pressure is about 15 millimetres (0.6 inch) of mercury above atmospheric pressure, so that if the anterior chamber is punctured by a hypodermic needle the aqueous humour flows out readily. Its function in maintaining the eye reasonably hard is seen by the collapse and wrinkling of the cornea when the fluid is allowed to escape. An additional function of the fluid is to provide nutrition for the crystalline lens and also for the cornea, both of which are devoid of blood vessels; the steady renewal and drainage serve to bring into the eye various nutrient substances, including glucose and amino acids, and to remove waste products of metabolism.

The vitreous body.

The vitreous body is a jelly. It is remarkable for the small amount of solid matter required to give it this semisolid structure; the solid material is made up of a form of collagen, vitrosin, and a mucopolysaccharide, hyaluronic acid. Thus, its composition is rather similar to that of the cornea, but the proportion of water is much greater, about 98 percent or more, compared with about 75 percent for the cornea. The jelly is probably secreted by certain cells of the retina. In general, the vitreous body is devoid of cells, in contrast with the lens, which is packed tight with cells. Embedded in the surface of the vitreous body, however, there is a population of specialized cells, the hyalocytes of Balazs, which may contribute to the breakdown and renewal of the hyaluronic acid. The

vitreous body serves to keep the underlying retina pressed against the choroid.

The crystalline lens.

The lens is a transparent body, flatter on its anterior than on its posterior surface, and suspended within the eye by the zonular fibres of Zinn attached to its equator; its anterior surface is bathed by aqueous humour, and its posterior surface by the vitreous body. The lens is a mass of tightly packed transparent fibrous cells, the lens fibres, enclosed in an elastic collagenous capsule. The lens fibres are arranged in sheets that form successive layers; the fibres run from pole to pole of the lens, the middle of a given fibre being in the equatorial region. On meridional (horizontal) section, the fibres are cut longitudinally to give an onion-scale appearance, whereas a section at right-angles to this--an equatorial section--would cut all the fibres across, and the result would be to give a honeycomb appearance. The epithelium, covering the anterior surface of the lens under the capsule, serves as the origin of the lens fibres, both during embryonic and fetal development and during infant and adult life, the lens continuing to grow by the laying down of new fibres throughout life.

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