Section B and C

Volume-13

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7. SYSTEM PHYSIOLOGY-ANIMALS

E. SENSE ORGANS

VISION

The eyes are very special, complex sense organs which house receptors sensitive to light rays (rods and cones) as well as an optic system to focus the light rays on the receptors in the retina. From the retina impulses are conducted along the optic nerve (N-II) to the visual (optic) area in the cerebral cortex where the visual images are "seen" and interpreted.

Anatomical organisation

The eyes are situated in the orbital cavities of the skull, the bony walls of which protect the eyes from injury. The eyes are furthermore protected anteriorly by the eyelids and eyelashes. The principal structures of the eyes are presented in figure.

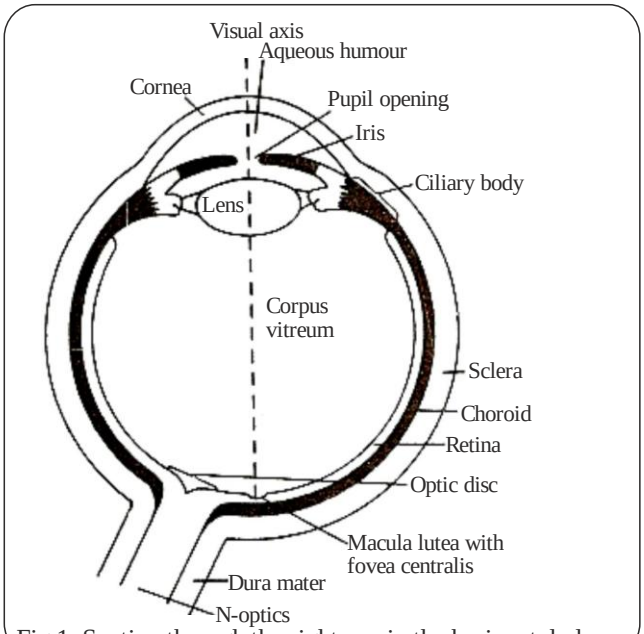

Fig.1: Section through the right eye in the horizontal plane

The eyeballs are more or less spheric, ≈ 24 mm in diameter. The eyelids are lined with an epithelial membrane which runs continuous with the membrane that covers the eyeball anteriorly (the conjunctiva). The conjunctiva contains numerous pain-sensitive nerve fibres, and very slight stimulation, e.g. the presence of a small foreign particle such as a grain of sand, elicits reflex blinking (the conjunctiva reflex). Simultaneously tears are produced to wash the foreign particle away. The conjunctiva is, in fact, always covered with a thin film of tears (lacrimal fluid). Tear fluid is formed by the tear gland, located in the upper, outer part of the eye socket; the ducts of the gland open behind the eyelids above the outer corner of the eye. Part of the tear

fluid evaporates, and the rest, especially when crying, flows from the inside corner of the eye into the nasal cavity through the lacrimal duct. Tears are composed of water and salts, and contain an enzyme, lysozyme. Tears protect the conjunctiva from desiccation and lubricate the eye. They also wash away any dust or grit from the anterior surface of the eye, and due to the presence of lysozyme, bacteria and other micro-organisms are destroyed. Inflammation of the conjunctiva (conjunctivitis, pink eye) is contagious and should be treated.

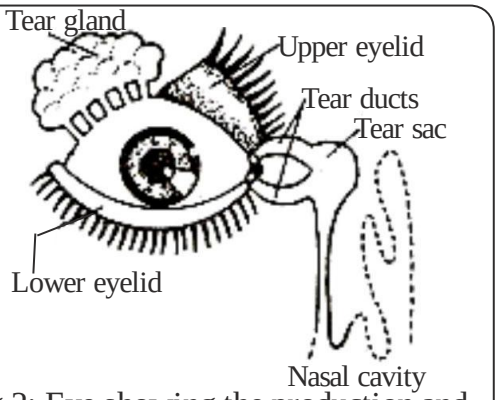

Fig.2: Eye showing the production and drainage of tears

The eyeballs are each moved by six external eye muscles. These muscles operate in a conjugated way and enable the eyes to carry out horizontal, vertical or rotational movements. They have double reciprocal motor nerve supply via N-III, IV and VI.

The eyeballs consist of three concentric layers of tissue:

1. The outer layer (tunica fibrosa) is a fibrous protective layer and is called the sclera (white of the eye). Anteriorly it is transparent and this part is known as the cornea. At the posterior pole of the eye where the optic nerve leaves the eyeball, the sclera is continuous with the dura mater, which forms a protective sheath around the optic nerve, and which in turn is continuous with the dura mater covering the brain.

2. The middle layer (tunica vasorum) is formed by (i) the choroid (posterior part) which contains many blood vessels, (ii) the more anterior thickened part, the ciliary body which contains the ciliary muscle fibres (the lens is attached to projections of the ciliary body by means of a circular lens ligament) and (iii) the coloured, most anterior part, the iris. The centre of the iris is pierced by the pupil. The iris contains circular muscle fibres which constrict opening of the pupil (M. constrictor pupillae) and radial muscle fibres which dilate the pupil (M. dilator pupillae).

Clear, gelatinous material, the corpus vitreum, fills the eyeball behind the lens. The space between the lens and cornea is filled with a clear fluid, the aqueous humour, which is produced from blood plasma in the capillaries of the choroid and ciliary body. It is absorbed into the canal of Schlemm, which drains into the venous blood. Disturbances in the formation or absorption (e.g. with eye infections or trauma) may result in accumulation of fluid, which in turn causes an increase in intra-ocular pressure, a condition called glaucoma. The increased pressure may compress the blood vessels supplying the retina and thus cause damage to the retina or eventually even blindness.

3. The inner layer (tunica nervosa retina) contains the visual receptors, the rods and cones. The rods are very sensitive and function in dim light (night vision), whereas the cones, with which colours are perceived, need relatively bright light or daylight to be stimulated. The rods are extremely sensitive to light and attain a lower limit of sensitivity of nearly only one quantum of light; they are however, able to perceive objects only indistinctly. The rods and cones synapse with bipolar nerve cells, which in turn synapse with ganglion cells. The axons of the ganglion cells converge and leave the eye as the optic nerve, slightly medial to the posterior pole of the eye, where the blood vessels enter the eyeball. This region, called the optic disc contains no rods or cones and is consequently known as the blind spot.

At the posterior pole of the eye, there is a small, yellow area in the retina, the macula lutea. This is where the fovea contrails, the point where visual acuity is greatest, is located. Only cones are present in the fovea centralis. There is considerable convergence of rods and cones on bipolar cells, and again of bipolar cells on ganglion cells. No convergence, however, takes place with regard to the cones present in the fovea centralis.

The lens is a transparent, elastic biconvex structure, which sometimes becomes turbid with advancing age. This impedes vision and the condition is known as cataract. The lens can be replaced surgically by a plastic lens. When the lens is removed, the eye is said to be aphakia and the condition is called aphakia. The elasticity of the lens also declines with age.

The blood vessels supplying the retina branch extensively in the superficial layers of the retina and can be seen through an ophthalmoscope. Such an examination can supply valuable clinical information concerning diseases that affect blood vessels, e.g. hypertension and diabetes mellitus.

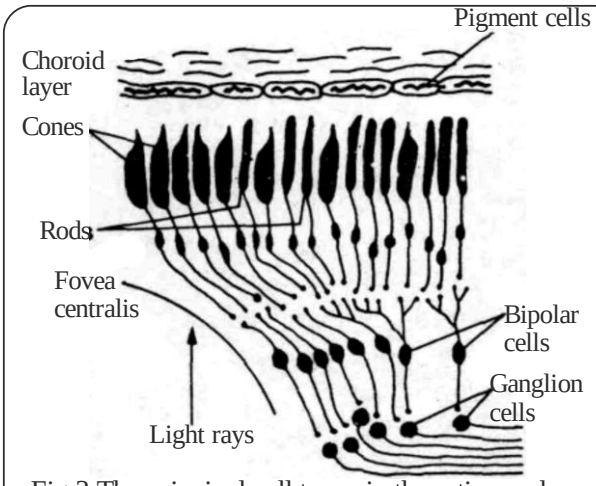

Fig.3:The principal cell types in the retina and their synaptic relations

All objects reflect light and the reflected light rays enter the eye through the transparent cornea and pupil. By means of the refractory power of the lens system of the eye an inverted and reduced image is formed on the retina, where the light energy is converted into nerve impulses.

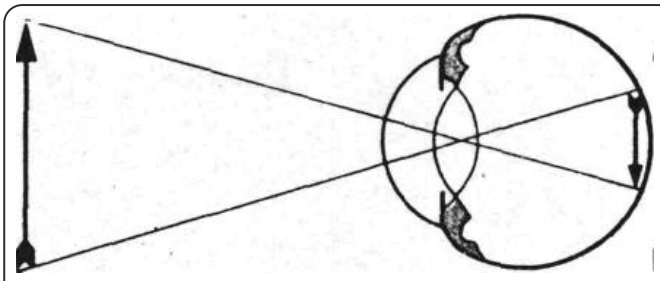

Fig.4: A simplified presentation of the formation of an image on the retina

Optic principles and image forming: When light rays pass from one medium into another, they are refracted (their direction is changed), except when they enter perpendicular to the interphase. Parallel light rays striking a biconvex lens are refracted or focused to a point behind the lens (principal focus). Light rays reflected from an object at an infinite distance are considered to be parallel; for practical purposes this means a distance of more than 6 metres from the eye. The distance from the lens to the principal focus (*f*) is the principal focus distance (*fa*). The principal focus distance is the criterion for the refractive power of a lens system the more powerful the lens, the closer is *f* and the shorter *fa*. The refractive power depends primarily upon the curvature of the lens the greater the curvature (the rounder or more convex the lens), the greater its refractive power. The unit for refractive power (D) is that of an optic system of which the principal focus distance is one metre. The unit is called diopter: $D = \frac{1}{fa} = \frac{1}{1m}$.

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