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CHAPTER 3 ANTERIOR SEGMENT OF THE EYE

A. INTRODUCTION

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1. The iris is a thin circular disc, corresponding to the diaphragm of a camera, and is perforated centrally by the pupil. The pupil varies in size and regulates the amount of light that reaches the retina. Even with the pupil at its maximum physiological size, the iris contributes to the quality of the retinal image by excluding the peripheral, less optically perfect, zones of the cornea and lens from participation in image formation. The iris sphincter, by contracting, constricts the pupil and increases the depth of focus of the eye.

   The iris is derived from two layers of mesoderm, the anterior of which originally stretches completely across the pupil as the pupillary membrane. This anterior layer atrophies from the centre peripherally past the pupillary margin to the collarette, a zig-zag line roughly parallel to the pupillary margin and 2 mm from it. The collarette divides the anterior surface of the iris into an outer or peripheral, ciliary zone, and an inner, pupillary zone. The ciliary zone is fairly smooth, but near its outer part several concentric lines are seen which become deeper as the pupil dilates. They correspond to the folds in the palm of the hand. In blue irides, the blood vessels may be seen in the stroma as radial white lines. In dark brown irides, pigmented cells in the stroma obscure the vessels. There is a heavy ring of dark brown pigment at the pupil margin. In the pupillary zone a whitish-grey band about 1 mm wide may be seen in eyes of some older patients when atrophy of the stroma is present. This is the sphincter of the iris. The iris is thinnest at its periphery which explains the frequency with which it tears away from the ciliary body as a result of contusion injuries (iridodialysis).

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2. The anterior chamber angle is hidden from direct examination by the sclera. The angle structures are examined clinically with a special contact lens (goniolens). The technique is called gonioscopy. Aqueous humour leaves the eye by flowing through the trabecular meshwork, into Schlemm's canal and thence into the episcleral and conjunctival blood vessels.

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3. Ciliary body. The cross-section of the ciliary body is triangular.

The anterior side of the triangle is the shortest. It enters into the formation of the anterior chamber angle and gives origin to the iris. The outer corner of this anterior side of the triangle is anchored to a tongue of sclera, the scleral spur.

The outer side of the triangle, composed of the ciliary muscle, lies against the sclera, the suprachoroidal space lying between them. The inner side of the triangle is best appreciated when the eye is viewed from its inner surface. Two zones will be noted:

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The pars plicata (or corona ciliaris) is the narrow (2mm) anterior portion characterised by about 70 meridional ridges known as the ciliary processes. These are responsible for aqueous humour formation.

The pars plana is a broad (4.5mm) posterior flattened portion of the ciliary body. It is continuous with choroid and retina posteriorly. Its union with the retina is marked by a scalloped line known as the ora serrata.

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4. The lens is suspended from the ciliary body by the zonules, fibres arising in the ciliary body and inserting into the lens capsule near its equator. When the ciliary muscle is relaxed, the zonules are taut and flatten the lens. Contraction of the ciliary muscle relaxes the zonules, and the lens assumes a more spherical shape which increases its refractive power (accommodation).

B. HISTOLOGY AND PHYSIOLOGY

1. The iris

Histologically the iris may be divided into two main portions according to its two different embryonic derivations:

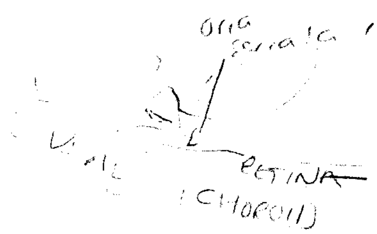
a) Uveal portion - from mesoderm.

   i) Anterior border layer
   ii) Stroma proper

b) Retinal portion - from neuroectoderm

   i) Muscles
      - Sphincter (parasympathetic)
      - Dilator (sympathetic)

   ii) Pigment epithelium



The anterior border layer is formed by condensation and intertwining of the processes of the stromal cells. It varies considerably in thickness and pigmentation in different eyes. Dehiscences in the anterior border layer and stroma are called iris crypts.

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The stroma is made up mostly of blood vessels. Since the iris is continually in motion, the vessels of the iris coil like springs in order to avoid kinking when the pupil dilates. Two vascular arcades run circumferentially, the major arterial circle at the root of the iris, and the minor circle in the stroma in the region of the collarette. Radial vessels connecting these two arcades comprise the main part of the iris vasculature. They form irregular radial elevations on the anterior surface of the iris.

The remainder of the stroma is made up of a very loose connective tissue, and the delicate non-pigmented processes of the stromal cells. The several other cell types present in the stroma are:

- Melanocytes with large branching processes which interconnect to form a syncytium.
- Pigmented 'clump cells' which appear to be cells of the posterior epithelium which have migrated forward into the stroma.
- Wandering macrophages.
- Neurones

The posterior layer of the iris is heavily pigmented by the fourth month of gestation, but in fair-skinned individuals the stroma at birth is free of pigment and the iris appears blue. If pigmentation in the anterior layers does not develop, the eyes will remain blue. In the adult iris, the darker the iris the more melanocytes there are in the stroma. In the dark-skinned races the anterior layers are already heavily pigmented at birth. In albinos there is complete absence of chromatophores in the anterior layers as well as a deficiency of the pigment in the deeper pigmented layers. Light reflected from the blood in the choroid passes through the iris and this along with blood in the vessels in the iris gives these eyes a pinkish colour (Waardenburg's sign).

The sphincter muscle surrounds the pupil and on contraction makes the pupil smaller. It is under the control of the parasympathetic nervous system, being supplied by the third cranial (oculomotor) nerve via the short ciliary nerves. Both the sphincter and dilator muscles are derived from neural ectoderm (the outer layer of the optic cup). However, the sphincter muscle cells migrate forward into the stroma and elongate into typical smooth muscle cells. The cells that form the dilator muscle differentiate into myoepithelial cells. Near the pupil, fibres of the dilator muscle connect to the sphincter muscle, while at the root of the iris they attach to the ciliary muscle, providing an anchor from which they can dilate the pupil on contraction. The dilator muscle is innervated by the sympathetic system.

The pigment epithelial layer of the iris is the only structure derived from the inner layer of the optic cup, which is pigmented. Posteriorly it is continuous with the inner non-pigmented layer of the ciliary epithelium and with the retina.

2. The ciliary body

The ciliary body is triangular in cross-section. Anteriorly it is firmly attached to the scleral spur and the iris and posteriorly to the choroid and retina. Externally it abuts against the sclera, but is not attached to it. Following trauma or inflammation the ciliary body may detach from the sclera. The ciliary body is composed of six layers, from without inwards, as follows:

a)	Ciliary muscle	}
b)	Vessel layer	} From mesoderm
c)	Lamina vitrea	} From outer layer
d)	Pigment epithelium	} of optic cup
e)	Ciliary epithelium	} From inner layer
f)	Internal limiting membrane	} of optic cup

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a) The ciliary muscle is a smooth muscle running circumferentially around the globe attaching to the scleral spur and related through it to the trabecular meshwork of the anterior chamber angle. The ciliary muscle is arranged into three parts:

Longitudinal (meridional) fibres from the outer layers. These arise anteriorly from the scleral spur and insert posteriorly into the choroid.

Circular fibres are the innermost bundles which run circumferentially.

Radial fibres are few and difficult to identify.

During ciliary muscle contraction the ciliary body moves forward slightly and the ciliary processes move inwards towards the antero-posterior axis of the globe. These movements lead to relaxation of the zonules, allowing the lens to become more nearly spherical and thereby increasing its refractive power (accommodation).

Accommodation is a reflex process, initiated by blurring of vision or by an awareness of proximity of the object of regard. The ciliary muscle is innervated by the parasympathetic system via the oculomotor nerve. The maximum amount of accommodation which can be exerted by a given eye is termed the amplitude of accommodation. It is measured by determining the closest distance from the eye at which fine print can be seen clearly. The accommodation in dioptres required at a given distance is the reciprocal of the distance (in metres) e.g. 1 metre - 1 dioptre, 20 cm - 5 dioptres, etc. The amplitude of accommodation is primarily dependent on the rigidity of the lens,which increases with age, and accommodation therefore decreases accordingly. This is a physiological process which occurs at a very predictable rate. In childhood more accommodative amplitude than is normally needed for reading is present (14 dioptres at age 10 years). Although accommodative amplitude decreases steadily from childhood on, the emmetropic individual does not experience difficulty with reading until the accommodative amplitude falls to the 4 dioptre level when near objects become blurred at the normal reading distance of 30 cm. Reading becomes impossible without optical assistance, and the patient is said to have 'presbyopia'. This usually occurs in emmetropic eyes at about age 45 years. Presbyopia is treated by adding plus power to the patient's refractive correction either as a bifocal or as a separate pair of reading glasses.

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b) The vessel layer of the ciliary body is in direct continuity with the vessel layer of the choroid. It makes up the bulk of the ciliary processes. Each ciliary process is a fold of connective tissue with a vascular core covered by the double-layered ciliary epithelium. Each process is supplied at its anterior end by a small arterial branch arising from the major arterial circle. This breaks up immediately into a system of broad capillaries. Venous blood drains posteriorly into the choroid.

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d) The pigment epithelium is continuous with the pigment epithelium of the retina.

e) The ciliary epithelium is a continuation of the sensory portion of the retina as a single layer of cells. It is non-pigmented except in the extreme anterior region where it continues forward as the pigment epithelium on the posterior surface of the iris. It is firmly attached to the pigment epithelium underlying it so that the two layers form a unit for transmitting the pull of the ciliary muscle to the zonule. Electron microscopy has revealed similarities to the distal convoluted tubule of the kidney, suggesting fluid transport.

f) The internal limiting membrane is a forward continuation of the similar structure in the retina, but the adjacent vitreous is more tightly adherent to the ciliary body internal limiting membrane than it is to the internal limiting membrane of the retina.

The zonular fibres arise from the pars plana, course forward through the valleys between the ciliary processes and then insert into the lens capsule close to the equator of the lens.

3. Aqueous humour

The crystal clear aqueous humour fills the anterior and posterior chambers and fulfils two main functions:

a) Maintenance of intraocular pressure.

b) Nourishment of the lens and cornea.

In the human eye the volume of aqueous is 200 to 300 microlitres (80% of this volume in the anterior chamber, 20% in the posterior chamber). The mechanism of production of aqueous is poorly understood, but it is now generally agreed that active transport systems in the ciliary epithelium 'secrete' certain substances into the posterior chamber, water and other substances following passively. Aqueous then flows through the pupil, into the anterior chamber and out of the eye at the anterior chamber angle.

The aqueous normally contains very little protein, 0.02 grams per 100ml and a high level of ascorbate.

The character of the aqueous changes markedly after even relatively mild trauma or inflammation in the eye, and is then called 'plasmoid aqueous.' The protein content rises markedly and in all other ways plasmoid aqueous tends to resemble plasma more closely than normal aqueous. Antibodies, normally present in very low titre in the aqueous because of the low protein content, rise to high titres in plasmoid aqueous. The occurrence of plasmoid aqueous is an expression of the breakdown of the normal blood-aqueous barrier, and facilitates the entry of antibodies and systemically administered antibiotics into the eye.

4. Anterior chamber angle.

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The 'angle' of the anterior chamber begins anteriorly at Schwalbe's line (g), the thickened edge of Descemet's membrane. A shallow sulcus in the internal surface of the sclera extends posteriorly from Schwalbe's line for about 0.75mm, ending at the scleral spur. The internal (towards the anterior chamber) part of this sulcus is filled with a fine endothelial-lined meshwork called the trabecular meshwork (f), while its external part is occupied by a large endothelial-lined vessel which runs circumferentially completely around the cornea, Schlemm's canal (a).

The trabecular meshwork is made up of multiple sheets, each with many pores stretching from Schwalbe's line to the scleral spur. The trabecular meshwork is triangular in meridional section, with its base at the scleral spur and the apex at Schwalbe's line. Each trabeculum is made up of a dense collagen core surrounded by an amorphous ground substance containing fine fibrils, surrounded in turn by endothelium.

Aqueous flows in random tortuous passages through the pores in the trabecular sheets. The pores near the anterior chamber measure 40 to 60µ in diameter and contribute little to the resistance to aqueous outflow. Further outward the pore size decreases and particles greater than 1u in size have difficulty in passing through. This area contributes at least three quarters of the resistance to the outflow of aqueous.

After the aqueous filters through the trabecular meshwork, it is collected in Schlemm's canal, which in turn is drained by 25-35 collector channels. Some of these continue as aqueous veins in the conjunctiva while others go directly to the episcleral veins.

Intraocular pressure - IOP.

The pressure of the fluid within the eye is dependent on the production of aqueous and the resistance to outflow of aqueous from the eye.

PRESSURE = AQUEOUS FLOW X RESISTANCE TO OUTFLOW

A homeostatic mechanism is present in normal eyes so that if aqueous secretion rises, outflow resistance decreases and vice versa. There are two clinically available methods of measuring intraocular pressure, both requiring a drop of topical anaesthetic and application of the measuring instrument to the cornea.

Indentation tonometry measures localised corneal indentation by a known force.

Applanation tonometry measures the force needed to flatten a known area of cornea.

The indentation method used today is called Schiotz tonometry. The measuring instrument consists of a weight on a plunger to which a measuring arm is attached. With the patient recumbent the instrument is placed on the cornea. The arm registers on a scale the amount the plunger indents the cornea. The method, although simple and practical, is subject to error and is not routinely used in ophthalmic practice.

Applanation tonometry, developed in practical form by Goldman in 1957, requires a slit lamp, but is very accurate.

The patients sits at the slit lamp and an applanation head containing 2 prisms is pressed against the cornea by a spring of adjustable tension. The force required to flatten a 3mm diameter circle of cornea is measured. The normal intraocular pressure is usually in the range of 10 to 21 mm Hg.

- A pressure of less than 10 is usually the result of surgery or some disease process which causes reduced output of aqueous by the ciliary body.

- Any pressure above 21 is 'suspicious' of a state termed ocular hypertension, and if it is associated with structural defects (optic disc cupping) or functional defects (visual field abnormalities), glaucoma is present.

The rate at which aqueous flows out of the eye can also be measured clinically by a procedure called tonography. A Schiotz tonometer is placed on the eye for a known period of time (usually four minutes). Measurement is made of the rate at which the pressure in the eye decreases as the weight on the cornea gradually forces aqueous out of the anterior chamber through the trabecular meshwork and Schlemm's canal.

5. The lens

The lens shares with the cornea the requirements of transparency, smooth spherical surface and appropriate index of refraction. Moreover, it must be sufficiently pliable to allow the changes in shape required for accommodation. The lens is even more isolated from the rest of the body than the cornea, its complete avascularity forcing it to derive all of its nutrition from the aqueous humour. Its thick elastic capsule prevents movement of large molecules such as proteins into or out of it.

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The structure of the lens is best understood in relation to its development. As the optic vesicle invaginates from the neural ectoderm, it induces a thickening in the surface ectoderm which is called the lens placode. The lens placode invaginates to form a hollow sphere or lens vesicle which is connected to the surface ectoderm for a short time by a stalk. Later, the lens, which is now a hollow sphere, comes to lie within the enlarging optic cup and its connection to the surface ectoderm disappears. Its wall is composed of a single layer of cells forming the lens capsule.

The cells of the anterior wall remain unchanged throughout life forming the lens epithelium, a single layer of cuboidal cells with basally situated nuclei. The cells of the posterior wall elongate anteriorly and fill up the cavity of the lens vesicle. These are the primary lens fibres. From this time on, the posterior lens surface is without an epithelium. Secondary lens 'fibres', each of which is an individual cell, are continuously formed throughout life by mitotic division of the epithelial cells at the equator of the lens. They grow anteriorly and posteriorly around the primary lens fibres, being laid down somewhat like the layers of an onion. The ends of the lens fibres meet anteriorly and posteriorly forming the lens sutures. Two major subdivisions of the lens substance are apparent in adult life, the central nucleus and the more peripheral cortex. The lens fibres, like other epithelial cells, continue to multiply throughout life. They cannot, however, be desquamated and thus the size of the lens gradually increases with age, the depth of the anterior chamber decreasing accordingly. This is one of the factors leading to closed angle glaucoma in eyes with shallow anterior chambers.

The lens is composed chiefly of water (65%) and protein (nearly all the remainder). The water content of the lens, particularly the nucleus, decreases with age and the lens becomes less pliable. This is the cause of presbyopia.

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The lens capsule is a regular lamellar structure, is secreted by the epithelial cells and is comparable to the basement membrane of other epithelial structures. The zonular fibres, which are continuous with the outer layer of the lens capsule (the zonular lamella), counteract its inherent elasticity and maintain the lens in a flatter shape than that to which the capsule tends to mould it. The lens capsule serves as an efficient barrier against the passage of protein molecules early in embryonic life, since lens proteins, unlike most other proteins of the body, are capable of stimulating the production of antibodies within the same individual animal. This curious situation presumably results because the lens proteins become isolated from the remainder of the body prior to the time when the organism by some unknown process becomes immunologically 'tolerant' of its own proteins, so that antibodies to them are not developed. Because of this lack of 'tolerance' individuals may develop antibodies to their own lens protein following an injury which damages the lens capsule.