

Basic and Clinical Science Course, AAO 2008-2009, Section 2, Chapter 2, pp 43-92.

The globe is the home of the retina (part of the embryonic forebrain, i.e. neural ectoderm and neural crest) which it protects, nourishes, moves or holds in proper position.

The retinal ganglion cells (**second neurons** of the visual pathway) have axons which form the optic nerve (a brain tract) and which connect to the lateral geniculate body of the brain (**third neurons** of the visual pathway with axons to cerebral cortex).

The **transparent media** of the eye are: tear film, cornea, aqueous, lens, vitreous, internal limiting membrane and inner retina.

Intraocular pressure is the pressure of the aqueous and vitreous compartment. The aqueous compartment is comprised of anterior (200ul) and posterior chamber (60ul).

**Aqueous and vitreous compartments** communicate across the anterior cortical gel of the vitreous which seen from up front looks like a donut and is called the “**annular diffusional gap.**”

The globe consists of two superimposed spheres, the **corneal radius** measuring 8mm and the **scleral radius** 12mm. The superimposition creates an **external scleral sulcus**, the outflow channels anterior to the scleral spur fill the **internal scleral sulcus**.

Three layers or **ocular coats** are distinguished: the corneal scleral coat, the uvea and neural retina consisting of retina and pigmented epithelium. The coats and components of the inner eye are held in place by intraocular pressure, scleral rigidity and mechanical attachments between the layers. The **corneoscleral coat** consists of cornea, sclera, lamina cribrosa and optic nerve sheath. It is perforated by the major perforating branches of the anterior ciliary arteries, the vortex veins and short and long posterior ciliary arteries.

There are mechanical attachments between lens, vitreous, retina, uvea and choroid. The lens is held in place by the zonular fibers originating from pars plana and vitreous base. The lens is also supported by the anterior cortical gel of the vitreous forming the **ligament of Wieger** at the lens periphery which encircles **Berger's space** (patellar fossa).

The **vitreous** itself is held in place by attachments to lens, vitreous base, optic nerve, blood vessels and fovea. The **retina** is attached to the pigmented epithelium at the optic nerve head and ora serrata and diffusely (fascially) to the vitreous fibrils.

The **uvea** has mechanical attachments to sclera at the entry of the long and short posterior ciliary vessels, the **border layer of Jacoby** (choroidal, prelaminar level) at the disc, the vortex veins and the major perforating branches of the anterior ciliary arteries at the ciliary body level.

The main attachment of the uvea however is at the **scleral spur** where the **longitudinal muscle of Brucke** (tensor choroidalis) inserts.

These attachments determine the configuration of choroidal elevations : **shallow anterior**=supraciliary, **quadrilobed**=to vortex insertion, **kissing**=scleral spur to short posterior ciliaries.

**The eyeball length** is 24mm (21-30mm), the **diameter** is 24mm, the **volume** is 6.5cc and the **weight** is 7.5grams.

**The poles** of the eye represent the corneal and (imaginary) scleral center and are connected by the geometric axis. **Meridional planes** pass through the anterior and posterior poles of the eye. Meridional planes may be horizontal, vertical or oblique. The **equatorial plane** lies midway between the anterior and posterior poles and is perpendicular to the meridional plane and the geometrical axis. The equatorial plane also divides the eye into an anterior and posterior segment.

**Distances from the limbus** are: pars plicata 1-2mm, ora serrata 8mm, **equator 14mm**, vortex 14-25mm

**Spiral of Tillaux:** Imaginary spiral line connecting insertions of recti clockwise in the right eye, counter-clockwise in the left eye.

**Distances of rectus insertions** from limbus: medial rectus 5.5mm, inferior rectus 6.6-6.9mm, lateral rectus 6.9mm, superior rectus 7.0-7.7mm. The lateral recti insert parallel to the limbus. Superior and inferior rectus insert obliquely, their tendons insert more anterior nasally. Each rectus muscle has two **anterior ciliary artery branches(ACA)** except for the lateral rectus muscle which has only one (lacrimal) artery branch.

Oblique muscles insert posterior and temporal on the globe.

**Superior oblique:** “tendinous” insertion and “covers” superior rectus. The tendon measures 10mm to the **trochlea** which is **attached to the frontal bone**. There is also a 10mm tendon to the belly of the superior oblique muscle which originates from the sphenoid bone.

**Inferior oblique:** “muscular” insertion and “covers” inferior rectus. The muscle measures 40mm in length=shortest muscle. Fascia to inferior rectus and orbital ligaments to medial and lateral rectus form a hammock (**suspensory ligament of Lockwood**)

Inferior oblique muscle inserts along the horizontal meridian of posterior sclera=submacular. Does not originate from annulus). Origin: maxilla

**Horizontal folds:** related to horizontal inferior oblique insertion in **hypotony** combined with thin sclera.

**Vortex veins:** 4-7 in number, usually 4mm posterior to the equator but also at the equator. Each quadrant has at least one vortex vein. Vortices empty into the superior and inferior orbital vein with respective orbital fissure and into **cavernous sinus**. Cave: postseptal cellulitis.

**Cornea:** Measurement 12mm horizontally, 11mm vertically, thickness 0.7mm at periphery and 0.5mm centrally

**Corneal layers:** 5-6 cell layers, surface cells, wing cells and basal cells. Bowman's layer is a condensation of anuclear anterior stroma, which is PAS negative. Stroma makes up 90% of corneal thickness. Fibrils criss-cross at 90 degree angles. Collagen I,III,V,VI.

**Descemet's membrane:** thickness 3 -12 microns, **anterior banded zone**, posterior non-banded zone. Rich in type IV collagen. Endothelium composed of hexagonal cells with serrated margins. The intercellular junctions project into anterior chamber.

**Scleral thickness** anteriorly 0.6mm, at the insertions of rectus muscles 0.3mm, at equator 0.5mm, and at posterior pole 1.0mm. Sclera proper has criss-crossing collagen, elastic fibers and openings for blood vessels. It is covered externally by episclera, including **episcleral vessels** and their anterior and posterior plexus and internally by pigmented **lamina fusca**, both important for "perpendicular" healing.

### The Limbus

**Clinicians's** limbus: Transition of clear cornea to opaque sclera (corneolimbic junction)

**Histologist's** limbus: transition of regular corneal stromal lamellae to irregular scleral stromal lamella. (peripherally convex line)

**Pathologist's** limbus: tissue roughly between external and internal scleral sulcus, 1-2mm wide. Internal scleral sulcus bordered by end of Descemet's membrane (corneolimbic junction) and scleral spur (limboscleral junction)

**Central margin: (corneolimbic)** line through end of Bowman's and Descemet's membrane

**Peripheral margin: (limboscleral)** line through scleral spur perpendicular to outer sclera.

**Angle components:** inner scleral sulcus, scleral spur, **arciform boundary**. Note: chamber "angle" is posterior and peripheral to trabecular meshwork.

**Trabecular meshwork:** uveal, corneoscleral meshwork, juxtacanalicular tissue and Schlemm's canal

Conventional outflow: trabecular meshwork

Nonconventional outflow: anterior ciliary body

**Conventional outflow of aqueous:** anterior chamber, uveal meshwork, corneoscleral meshwork, juxtacanalicular tissue, sinus venosus (canal of **Schlemm**), collector channels (of **Sondermann**), aqueous veins (of **Ascher**), episcleral veins

**Uvea:** iris, ciliary body, choroid

**Uveal borders:** iris root, ora serrata, border tissue of Elschnig

Uveal attachments: scleral spur, major perforating branches of anterior ciliary arteries, vortex veins, posterior ciliary vessels, optic nerve

Note difference in anterior point of attachment: Uveal effusion = scleral spur. Retinal detachment = ora serrata. The posterior attachment point for both are the optic nerve axons.

**Iris:** Central **pupillary portion** and peripheral **ciliary portion** of the iris stroma are divided by **collarette**. The ciliary portion attached to ciliary body at iris root. Rupture of iris root: iridodialysis.

**Iris layers** anteriorly: anterior border layer, stroma, blood vessels, bilayered neuroepithelium.

No epithelium covers the anterior iris surface. Anterior border layer is composed of fibroblasts and melanocytes. Both iris sphincter and dilator are neuroectodermal

derivations. Sphincter and dilator are attached to each other at the **central Fuchs' spur** and **peripheral Michael's spur**.

Peripheral iris and ciliary sulcus epithelium have the densest pigmentation. (sulcus fixation of IOL = iatrogenic depigmentation)

**Iris dilator:** sympathetic. Hypothalamus, synapse C8, superior cervical ganglion, carotid, long posterior ciliary nerves.

**Iris sphincter:** parasympathetic. Edinger-Westphal, oculomotor, cavernous sinus, inferior oblique, **synapse ciliary ganglion**, short ciliary nerves.

The iris epithelium is a bilayer: apex to apex. The anterior layer has myoepithelial-like (dilator) differentiation. The posterior layer is more densely pigmented.

**Ciliary body:** As part of uvea, components are epithelium and stroma (including ciliary muscle)

**Pars plicata:** major and minor processes. There are 60-70 ciliary processes. Pars plicata (corona ciliaris) is found at 1mm posterior to the limbus and measures 2mm anteroposteriorly.

**Pars plana:** ora bays and dentate processes (of the retina) The pars plana (orbiculus ciliaris) measures 4mm anterior- posteriorly

The **ciliary muscle:** longitudinal muscle (**Brucke's muscle=tensor choroidealis**) oblique and circumferential muscle fibers.

**Choroidal thickness:** at optic nerve 0.25mm at ora serrata 0.1mm.

**Choroidal layers:** Bruch's membrane, choriocapillaris, subcapillary fibrous tissue, medium vessels(Sattler's layer), large vessels(Haller's layer), lymphatics and nerves.

**Vascular sandwich:** RPE pigment, vessels, outer choroidal pigment.

**Fibrous structure of the choriocapillaris:** Bruch's membrane, intercapillary bridges, subcapillary fibrous tissue.

**Choroid:** choriocapillaris, slits, medium and large vessels.

**Choriocapillaris:** "choroidocapillaris", lobules, precapillary arterioles, postcapillary venules.

**Bruch's membrane:** basal lamina of the RPE, collagenous layer(thick), elastic tissue, collagenous layer(thin), basal lamina of choriocapillaris, intercapillary bridges.

**Lens:** diameter: 10mm, lens epithelium, nuclear bow, lens sutures and lens zonules. The lens capsule measures between 24 – 4 microns. (4 microns centrally where you polish.)

The lens fibers are 14mm long. **Lens zonules** (capsular fibers) can be divided into **cilioanterior, cilioequatorial and cilioposterior**. The **orbiculoanterior** and **orbiculo posterior** fibers originate from the dentate processes of the retina, form the **orbiculohyaloidal interspace of Hannover**, rest on the anterior hyaloid and "suspend" the anterior vitreous.

**Apex to apex arrangement** of the optic cup: Apex in, basement membrane out

**Subretinal space:** potential space between retina – RPE

Subretinal space borders: border tissue of Kuhnt (**posterior cul-de-sac**) – ora serrata (**anterior cul-de-sac**)

**Suprachoroidal space:** potential space between choroid-sclera

Suprachoroidal space borders: **border tissue of Elschnig** (posterior cul-de-sac) – **scleral spur** (anterior cul-de-sac)

**Homology:** retina-brain, choroid-leptomeninges, sclera-dura

**Neurosensory retinal layers:** internal limiting membrane, nerve fiber layer, ganglion cell layer(second neuron), inner plexiform layer, inner nuclear layer=bipolar layer(first neuron), outer plexiform layer, outer nuclear layer, external limiting membrane, rods and cones.

**Inner nuclear layer:** superficial capillary layer, amacrine cells=inside, bipolar and Mueller cells, horizontal cells=outside, deep capillary layer.

**Outer plexiform layer:** rod spherules, cone pedicles, horizontal cell processes.

**Middle limiting membrane:** junctional complexes between rod spherules and cone pedicles.

**Inner plexiform layer:** bipolar cell processes, amacrine cell processes, ganglion cell processes.

Simplified layer anatomy of the retina:

First, remember that the outer nuclear layer(receptor layer) consists of **rods and cones**.

Second, remember that the **nerve fiber layer and ganglion cell layer** consists of ganglion cells and their axons.

Thirdly, concentrate on the inner nuclear layer because it contains bipolar cells and is therefore called “**bipolar layer**”( first neuron). The inner nuclear layer also houses the Muellerian cell body which is the structural backbone of the retina. On the inside of the bipolar cell layer are located the **amacrine cells** for horizontal connections. On the outside of the bipolar cell layer are the **horizontal cells** also for horizontal connections, Furthermore, **plexiform layers (outer and inner)** are found on either side of the inner nuclear (bipolar) layer

This is what one really needs to know.

From the above follows:

The bipolar cell processes and inner amacrine processes connect to the ganglion cell processes in the **inner plexiform layer**.

The horizontal cells which are located on the external side of the inner nuclear layer and the bipolar cell processes will connect to rod-spherules and cone-pedicles in the **outer plexiform layer**.

The outer plexiform layer is somewhat special in that only the inner third is truly plexiform. The inner 1/3 is separated from the outer 2/3rds by the **middle limiting membrane** which is composed of synapses and their junctional systems connecting the axons of rods and cones (inner fibers of Henle) to the outer neurons. The middle limiting membrane denotes the limit of retinal capillaries as well as a barrier to exudates.

A word about **radial glia of Mueller** cells: Mueller cell nuclei are located in the inner nuclear (bipolar) layer. The cells are invested by a rich superficial and deep capillary

plexus and suffer in retinal vascular disease( CRAO, Sickle, Diabetes). Mueller cells elaborate the internal limiting membrane which is their cell base (base in, apex out). The Mueller cell apex points to the photoreceptors and elaborates the external limiting membrane, a desmosomal junctional system. The apical processes of Mueller cells communicate with the apical villous processes of pigment epithelial cells (apex to apex) and guarantee the well being of both photoreceptors and neurons.

**Retinal bloodvessels:** branch arteries, radial peripapillary net, superficial capillary plexus, deep capillary plexus, radicular vessels.

**Blood supply of retina:** Capillaries derived from central retinal artery supply as external as inner nuclear layer. Outer (photoreceptor) layers are supplied by choriocapillaris. . 80% of the retinal nutrition comes from the choroid.

**Macular blood supply:** temporal short and long posterior ciliary vessels, “macular artery”

**Central retinal artery** loses internal elastic lamina near disc. The wall has smooth muscle layers, 5-7 at disc, 2-3 at equator, 1-2 peripherally.

**Macula:** (Central area) Histologically more than one ganglion cell layer, about one half of all ganglioncells of the retina are in central area. Topographically between disc and major temporal arcades (5.5mm diameter)

**Umbo:** center(navel). **Foveola** 0.3mm, **Fovea** 1.5mm diameter, **Parafovea** 0.5mm belt, **Perifovea** 1.5mm belt

**Foveola:** Only cones and elongated Mueller cells, only external nuclear photoreceptor) layer(other neurons and glia are laterally displaced). It represents the **bottom** of the fovea, is nourished by choroid , is 0.13mm thin and is rod-free=cone-only.

**Foveal avascular zone:** 250-600 micrometers diameter

**Foveal margin:** periphery of foveal declivity, margin 0.55mm thick,

**Fovea:** 1.5mm distance from margin to margin (1.5mm foveal diameter)

**Peripheral retina:** (extra areal retina):

Belt of near periphery	1.5mm wide.
Belt of middle periphery(equator)	3.0mm wide
Belt of far periphery	10-16mm wide

Extreme periphery corresponds to the ora serrata

Retinal thickness:

At optic nerve - 0.23 mm

At ora serrata - 0.11mm

**Ora Serrata:** (extreme periphery) border between nonpigmented epithelium and peripheral retina. Also border of Mueller cell presence and ring of vitreous attachment(base), two mm wide. The Mueller cell apices connect to the apical non-pigmented epithelial cells. Dentate processes of the retina are more prominent nasally. Cystoid degeneration is more prominent temporally (Blessig Ivanoff cysts)

**Optic Nerve:** 50mm in length overall,

intracranial 10mm

intracranicular 6mm

intraorbital 33mm

intraocular 0.7mm

diameter at scleral canal - 1.5mm

posterior to globe, the diameter is 3.4mm related to myelination by oligodendroglia.

Meninges surround disc posterior to globe. Dura connects to sclera, leptomeninges to choroid. The **border layer of Kuhnt** is at the level of the retina and the **border layer of Elschnig(fibrous, temporal)** and the border layer of **Jacoby(glial)** at the choroidal level  
General principle: Border tissues are glial tissues that separate retinal pigment epithelium and axons from choroid and sclera

The optic nerve rim is also characterized by the termination of Muller cells. Anteriorly, Mueller cells terminate at ora serrata, external limiting membrane unites with RPE cell apices. Posteriorly Mueller cells terminate at disc, external limiting membrane unites with RPE cell apices.

Where Muller cells end, the BM thickness changes, associated with strong vitreous attachments: vitreous base, peripapillary ring

**Vitreous:** two macromolecules, collagen and hyaluronic acid

Aqueous-Vitreous Compartments

Vitreous **attachments:** lens: ligament of Wieger, vitreous base, retinal vessels, perifovea: "peephole", optic nerve: "Weiss Ring".

**Ligamentum Hyaloideocapsulare of Wieger:** insertion of cilioposterior fibers, tractus hyaloideus, peripheral boundary of Berger's space.

**Spatium retrolentalis Berger:** potential space between posterior lens capsule and patellar fossa=anterior cortical gel

**Canal of Petit:** Space between posterior zonules and anterior cortical gel. May contain pigment, blood, air.

**Orbiculohyaloidal Space of Hannover:** between anterior and posterior zonules.

**Cloquet's Canal:** posterior to central cortical gel, funnel to area of Martegiani.

**Area of Martegiani:** circular vitreous cortical defect above optic nerve=papilla

Intraocular spaces: extrahyaloid, intrahyaloid.

**ANATOMY SHOULD KEEP PACE....**