Basic anatomy and physiology

Rapid Ophthalmology, First Edition. Zahir Mirza.

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Note that anatomical layers are described in order from the outer surface of the eye to the inner core.

Osteology of the orbit

ORBITAL FLOOR Maxilla, zygoma, palatine bone.

ORBITAL ROOF Frontal bone, lesser wing of sphenoid.

MEDIAL WALL Maxilla, lacrimal bone, ethmoid, body of sphenoid.

LATERAL WALL Zygomatic bone, greater wing of sphenoid.

Orbital fissures

Superior orbital fissure (Figure 1)

TRANSMITS Lacrimal nerve
Frontal nerve
Trochlear nerve
Superior division of oculomotor nerve
Nasociliary nerve
Inferior division of oculomotor nerve
Abducent nerve

Superior ophthalmic vein
Inferior ophthalmic vein

Inferior orbital fissure

TRANSMITS Infraorbital nerve
Zygomatic nerve
Branches from the pterygopalatine ganglion

Optic canal

TRANSMITS Optic nerve
Ophthalmic artery

The globe

DIMENSIONS Approximate sphere of 2.5 cm diameter
Axial length 24 mm
Volume 5.5 cm^3

LAYERS Superficial to deep: corneoscleral, uveal tract, neural layer.

Cornea (Figure 2)

DIMENSIONS Vertical diameter 10.6 mm
Horizontal diameter 11.7 mm

LAYERS Superficial to deep; corneal epithelium, Bowman's layer, stroma, Descemet's membrane, corneal endothelium.

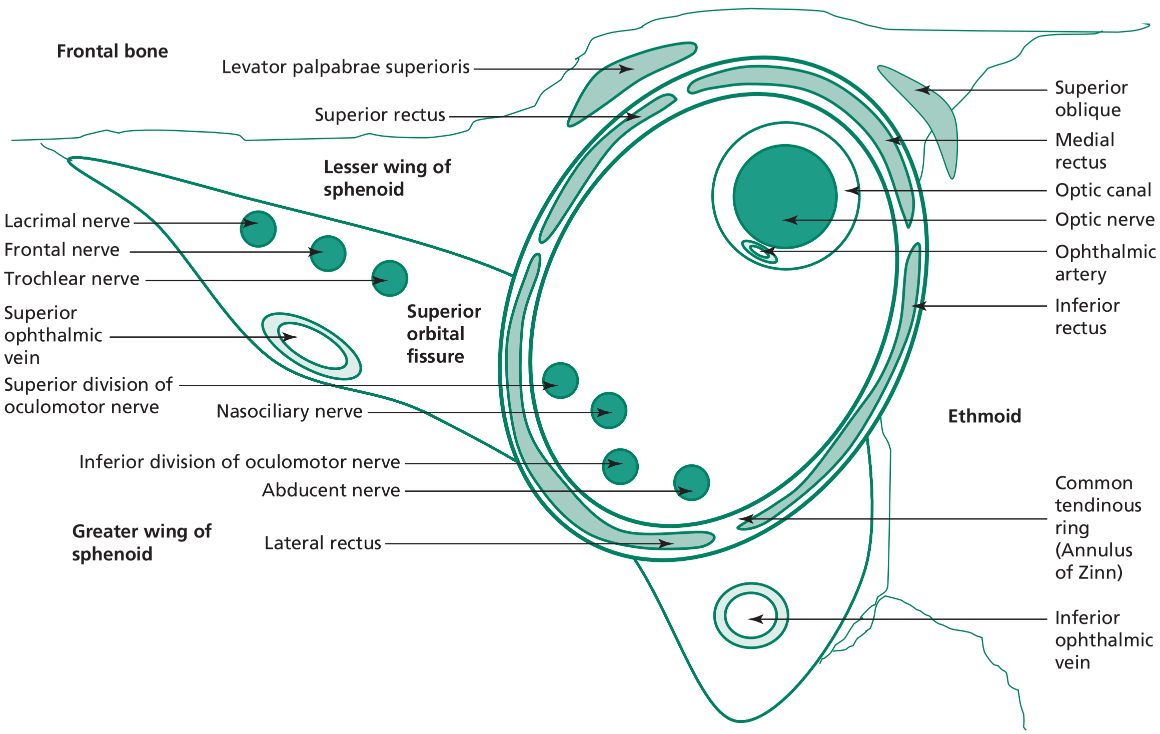

Figure 1 Diagram of the right orbit showing structures passing through the superior orbital fissure (cross section with the globe not included).

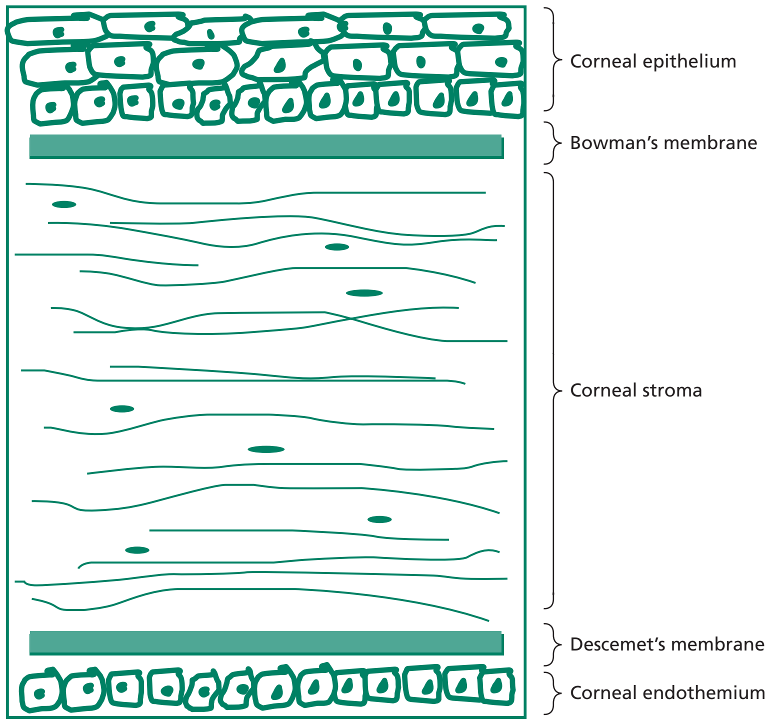

Figure 2 Diagram of a cross-section through the cornea.

SENSORY INNERVATION Ophthalmic division of the trigeminal nerve.

Anatomical terms

ORBITAL SEPTUM Layer of fascia within the eyelids arising from the periosteum of the orbital rim.

LIMBUS Junction between cornea and sclera.

UVEAL TRACT Comprises the iris, ciliary body and choroid.

CHOROID Vascular connective tissue between the sclera and retina. It nourishes the outer third of the retinal. The fovea is dependent on this blood supply for nourishment.

ANTERIOR SEGMENT Portion of the eye between the cornea and the anterior surface of the vitreous humour.

POSTERIOR SEGMENT Posterior two-thirds of the eye that contains the vitreous humour, optic disc, retina, most of the sclera and choroid.

ANTERIOR CHAMBER Formed by the cornea anteriorly and the iris posteriorly.

POSTERIOR CHAMBER Formed by the iris anteriorly and the lens posteriorly.

MACULA LUTEA Yellow area at the centre of the posterior retina that gives rise to fine vision owing to a high concentration of cone receptors.

FOVEA CENTRALIS A depression within the centre of the macula; it provides the most distinct vision as it has the highest density of cone receptors. Inner retinal layers are displaced laterally, hence the depression.

OPTIC DISC The optic nerve and central retinal vessels enter and leave the globe at this site. There are no photoreceptors at the optic disc, hence there is no visual perception of light falling onto this region. Therefore this area gives rise to the blind spot.

Retinal overview

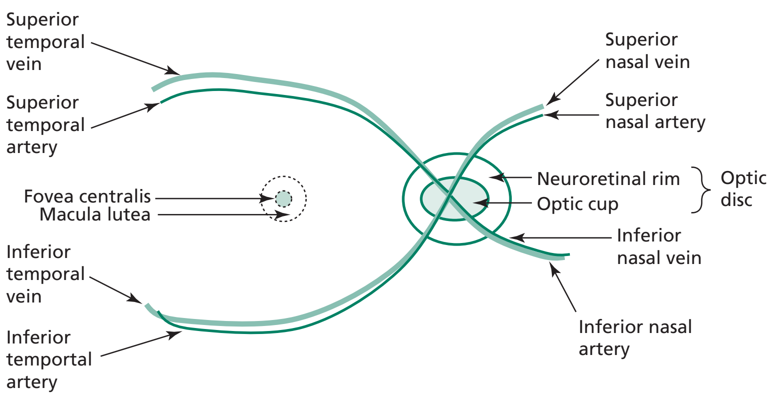

Figure 3 Schematic diagram showing clinical terms used to describe regions of the retina.

Layers of the retina

Lying on the retinal pigment epithelium (RPE) are three cell types in series that form the neurosensory retina; photoreceptive rods and cones, interneurones and ganglion cells. The RPE provides physiological support to the overlying neurosensory retina. The neurosensory retina converts light to neural impulses.

Figure 4 is a picture, obtained from ocular coherence tomography, that shows almost histological anatomical detail of retinal layers.

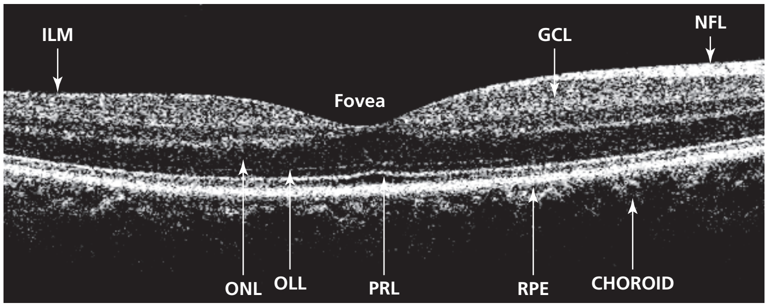

Figure 4 Ocular coherence tomography scan of the retina.
RPE – retinal pigment epithelium (and Bruch's membrane); PRL – photoreceptor layer; OLL – outer limiting layer; ONL – outer nuclear layer; GCL – ganglion cell layer; NFL – nerve fibre layer; ILM – inner limiting membrane.

Blood supply to the eye

Branches of the ophthalmic artery, which is the first cavernous branch of the internal carotid artery, supply the eye (important branches listed below):

Central retinal artery – supplies the inner two-thirds of the retina; however, there are no capillaries from branches of this artery supplying the fovea.
Short posterior ciliary arteries – supply the choroid.
Long posterior ciliary arteries – supply the iris and ciliary body.
Lacrimal artery – supplies lacrimal gland and eyelids.

Ciliary body and lens

This structure joins the choroid to the iris and features specialized surface folds (ciliary processes) that secrete aqueous humour. Through fine filaments (zonules) it supports the lens. Contraction of the ciliary body's muscular component relaxes the zonules and causes the lens to assume a more convex shape and thus allows focusing for near vision (accommodation). The lens is a transparent structure contained in an elastic capsular membrane located posterior to the pupil and iris and anterior to the vitreous.

Trabecular meshwork

Located within the angle between the cornea and iris, this structure is responsible for draining 90% of the aqueous fluid.

Aqueous humour flow

Aqueous humour flows from the posterior chamber, through the pupil and into the anterior chamber. It is taken up by the trabecular meshwork which drains aqueous filled vacuoles into a collecting channel known as Schlemm's canal. These drain into the vortex veins that contribute to the venous drainage of the eye.

Tears

Every blink recreates a three-layer tear film that coats the ocular surface.

From anterior to posterior:

Lipid (from eyelid Meibomian glands)
Aqueous (from the lacrimal gland and accessory conjunctival lacrimal glands)
Mucin (from conjunctival Goblet cells)

Vitreous humour

The transparent gel-like substance that occupies the posterior segment of the eye. It is composed 99% of water with collagen, hyaluronic acid and other proteins forming the remainder.

Ocular muscles (origin / insertion / primary actions [Figure 5])

Superior rectus (SR)

Origin – common tendinous ring
Insertion – sclera
Innervation – cranial nerve III (superior division)
Primary action – elevation of the globe

Inferior rectus (IR)

Origin – common tendinous ring
Insertion – sclera
Innervation – cranial nerve III (inferior division)
Primary action – depression of the globe

Medial rectus (MR)

Origin – common tendinous ring
Insertion – sclera
Innervation – cranial nerve III (inferior division)
Primary action – adduction

Lateral rectus (LR)

Origin – common tendinous ring
Insertion – sclera
Innervation – cranial nerve VI
Primary action – abduction

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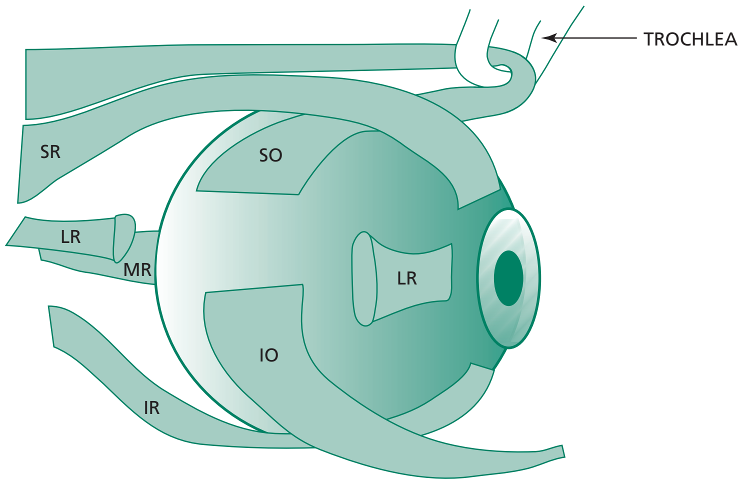


Figure 5 Schematic diagram using a lateral view to show the approximate insertions of extraocular muscles onto the globe. Note that a portion of the lateral rectus has been removed in this diagram in order to show the insertions of the oblique muscles. Also, the medial rectus inserts onto the medial aspect of the globe thus its insertion cannot be visualized from this view.

Superior oblique (SO)

Origin – sphenoid bone; however, its functional origin is from the trochlea which acts like a pully
Insertion – sclera
Innervation – cranial nerve IV
Primary action – intorsion (the secondary action is depression, especially in the adducted position)

Inferior oblique (IO)

Origin – anterior orbital floor
Insertion – sclera
Innervation – cranial nerve III (inferior division)
Primary action – extorsion (the secondary action is elevation in adduction)

The visual pathway (Figures 6 and 7)

The nasal retinal receives light from the temporal visual field and the temporal retina receives light from the nasal visual field. Photoreceptors within the retina act as the first-order neurones in the visual pathway. These then synapse with bipolar cells (second-order neurones) which synapse with ganglion cells (third-order neurones). The optic nerve contains axons from these ganglion cells.

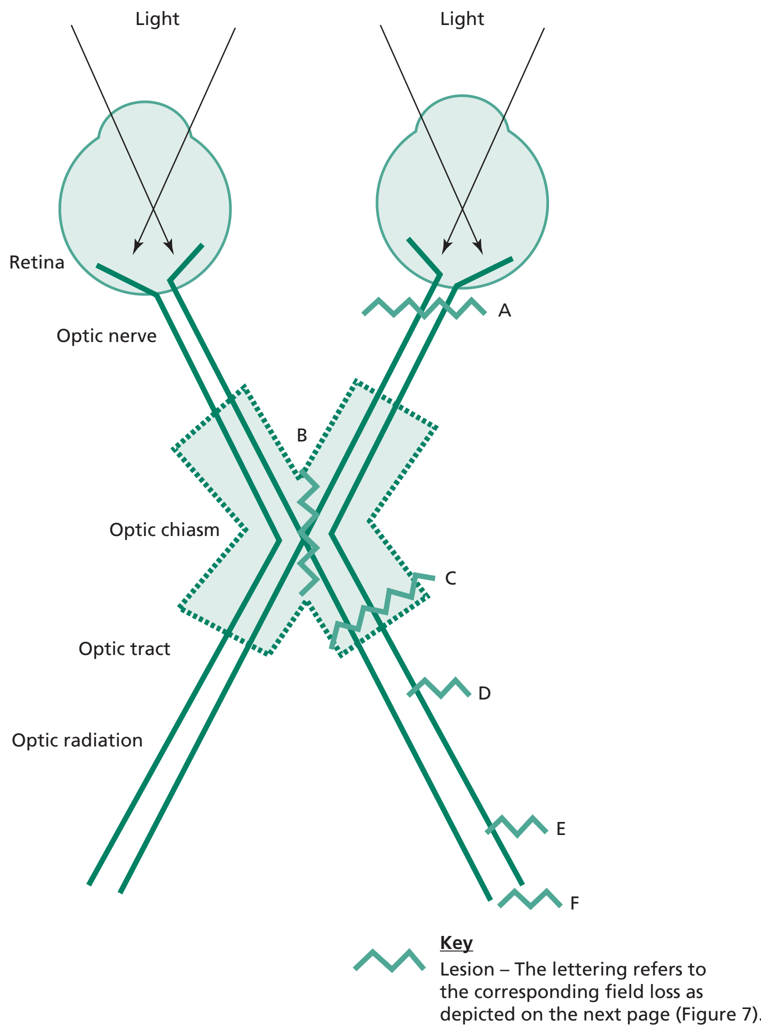
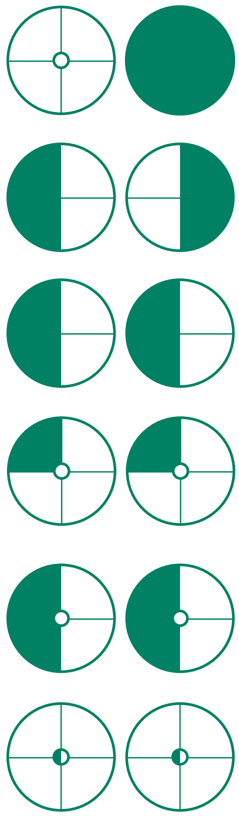


Figure 6 The visual pathway.

The fibres of the optic nerve converge at the optic chiasm and here fibres from the nasal retina cross over. Fibres from the temporal retina remain uncrossed. The optic tracts commence posterior to the chiasm and connect to the lateral geniculate body.

The axons of the lateral geniculate body travel via the optic radiations in the temporal and parietal lobes to the primary visual cortex in the occipital lobe.



A – Left optic nerve
Ipsilateral blindness with normal contralateral visual field
Causes include optic neuritis, ischaemic optic neuropathy, chronic papilloedema

B – Optic chiasm
Bitemporal hemianopia
Causes include pituitary lesions such as tumours or apoplexy, aneurysms, craniopharyngiomas or suprasellar meningioma

C – Optic tract
Contralateral homonymous hemianopia
Causes include stroke, tumours or trauma

D – Optic radiation – temporal lobe
Superior quadrantanopia – This would correspond to a lesion in the anterior and inferior loops of the optic radiation in the temporal lobe. These areas may be affected by tumours, infection or vascular lesions

E – Optic radiation – Posterior pariatal and occipital lobe
Homonymous hemianopia with macular sparing. Posterior cerebral artery occlusion with occipital infarction may spare the macular due to its large representation in the occipital lobe or due to collateral blood supply to the areas representing the macular

F – Tip of the occipital lobe
Homonymous hemianopic scotomas caused, for example, by a lesion of the tip of the occipital lobe

Note, lesions are described as if affecting the left side as shown in Figure 6.

Figure 7 Visual field defects.

Pupillary reflexes

Direct and consensual light reflex

Pathway: uniocular light stimulus – retinal stimulation – optic nerve – ipsilateral pretectal nucleus – bilateral sympathetic nuclei of cranial nerve (CN) III (Edinger-Westphal) – CN III (via ciliary ganglion) – iris sphinter pupillae muscles of each eye – bilateral pupil constriction (miosis)

Accommodation

Pathway: change in fixation from a distant target to near – retinal stimulation – optic nerve – visual cortex – descending fibres from cortex – then fibres travel through one of two pathways:

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(a) most fibres travel to cause convergence; internal capsule – midbrain – oculomotor nuclei – oculomotor nerve to medial recti – both medial recti contract – convergence of visual axes;
(b) some synapse bilaterally with Edinger-Westphal nuclei (parasympathetic fibres) – CN III (via ciliary ganglion) – ciliary muscle (causing the lens to assume a more convex shape with greater refractive power) and iris sphinter pupillae muscles of each eye (causing bilateral pupil constriction).

Pupil defects

Holmes-Adie pupil

A mid-dilated pupil with very slow reaction to light and a normal or slow reaction to accommodation. Recovery from constriction is slow. It is unilateral in 80% of cases but can progress to become bilateral thus mimicking Argyll Robertson pupils. It typically affects young women. Holmes-Adie syndrome features these findings in association with absent knee/ankle jerk.

Essential anisocoria

This is sometimes referred to as 'physiological anisicoria'. The pupils are of a different size but all pupil reactions are normal. It is estimated that 20% of the normal population have pupils of a different size with no underlying pathological cause.

Argyll Robertson pupils

Both pupils are small and irregular pupils. They react to accommodation but not to light and are found in neurosyphilis and diabetic autonomic neuropathy.

Horner's syndrome

A Miotic pupil with 2 mm of ptosis and unilateral anhydrosis of the upper face (see Horner's syndrome, below, **p. 85**).

Cranial nerve III palsy (complete)

Fixed and dilated pupil with ptosis and an eye that is abducted and depressed (down and out).

Relative afferent pupillary defect (RAPD) or Marcus Gunn pupil

Following direct stimulation of a pupil by light, both pupils constrict in normal eyes. In the presence of a relative afferent papillary defect the following sequence would be observed:

1. Light shone on the normal pupil – constriction of both pupils.

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2. Light then swung on to abnormal pupil – dilation of the (abnormal) pupil onto which the light is being shone (and simultaneous dilatation of the normal pupil).

A RAPD indicates a reduction in the afferent input from the retina of the abnormal eye compared to the normal eye because of an optic nerve defect in the former. There may be no RAPD if the optic nerves are equally abnormal.

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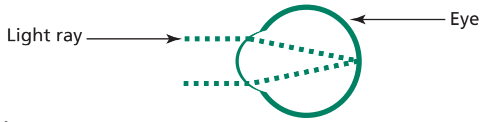
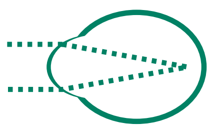
Myopia, hypermetropia and astigmatism

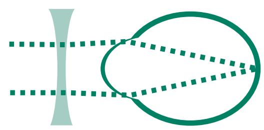
Emmetropia
Light is brought to focus at the fovea



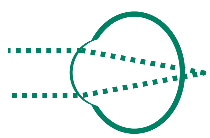
Myopia
Light is brought to focus in front of the fovea



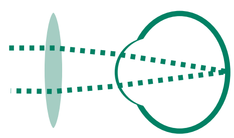
A concave diverging lens will correct myopia



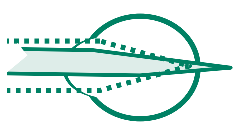
Hypermetropia
Light is brought to focus in behind fovea



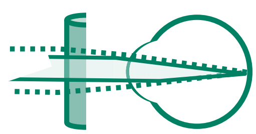
A convex converging lens will correct hypermetropia



Regular astigmatism
The refractive power of the eye varies due to unequal curvature of a refractive surface. The axes of greatest and least refractive power are at 90 degrees to each other. Often this is due to a compressed corneal shape (sometimes described as a rugby ball shaped cornea).



A toric lens will correct regular astigmatism



Irregular astigmatism
An irregularly shaped cornea focuses light at various different points and the axis of greatest and least focussing power are not at 90 degrees to each other.

Soft contact lenses cannot correct irregular astigmatism. A rigid contact lens will correct irregular astigmatism by 'replacing' the corneal surface.

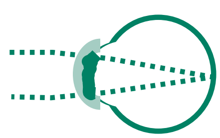


Figure 8 Refractive errors.