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Eye Anatomy

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Based in part on the previous version of this eLS article 'Eye Anatomy' (2002) by Thomas C Litzinger and Katia Del Rio-Tsonis.

Eyes are like windows to the outside world, but their intricacies and functionalities are far more extensive than those of any given glass window. They are able to capture, adjust, and transform light into a chemical code that only the brain can decipher. Each structure of the eye works in accord with the next – refracting, constricting, dilating and chemically reacting to convert patterns of light. This article uses the mammalian eye as a primary model and follows the path that light takes on its journey through the functional eye, detailing the essential components of one of the smallest, yet most complex organs in the body. Many have attempted to emulate its abilities, but even top-of-the-line digital single lens reflex cameras dare not compare with the elegant, efficient design infused in this multifaceted unit of anatomical machinery.

Introduction

The eye has been described by Charles Darwin as both perfect and complex. There are several structural and functional variations of the 'eye' that exist amongst organisms, yet it would be incorrect to say that one is more superior to another. This is the perfection that the eye beholds; each eye has evolved precisely to suit the necessities of its possessor. The simplest 'eyes', known as eyespots, are present in some unicellular organisms and many metazoa that use photoreceptor proteins and pigments to detect light from the surrounding environment and respond by adjusting their internal circadian rhythms to the daily light–dark cycle. The more complex optical systems that are found in 96% of animal species, however, are able to harness light from the environment, regulate its intensity through a diaphragm and focus it using an adjustable lens to form a pattern of light (Land and

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Introductory article

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Fernald, 1992). Many parts of the vertebrate eye play critical roles and work closely in harmony with the rest to function as a window to the world.

The Vertebrate Eye: Mammals as a Primary Model

Vertebrate eyes are roughly spherical. As light encounters the eye, it is slowed down, bent, absorbed and converted into electrochemical impulses to be processed by the brain. As light approaches the eye, it first comes into contact with the cornea. The cornea refracts the light and allows it to converge inside the eye on its way to the iris and pupil. Depending on the intensity and availability of light, the iris will contract or expand in order to adjust the pupil size, thereby, regulating the amount of light that can enter the eye. In low-light environments, the pupil will be larger, so that sufficient light can pass and form a discernible image. The opposite is true when light is abundant, since excess light results in poor imaging (Bruce *et al.*, 1996). Once through the gate of the pupil, the light is received by the lens, which is able to change its shape with the aid of auxiliary muscles and bring objects at various distances into focus through the process of accommodation. The lens also slightly improves the already refined image from the cornea and projects it onto the retina. The retina, which literally means 'net', catches the light via its photoreceptor and pigmented epithelial cells. The photopigment molecules of these photoreceptors absorb the light, leading to a change in electrical signals. This conversion of light energy to electrical impulses initiates a series of signals that travel through the neurons of the retina and into the optic nerve, leading to the brain. These signals are then received and processed by the brain as perceived images (Purves *et al.*, 1997; Figure 1a).

Structures Involved in Refracting and Focusing Light

The cornea

As mentioned, upon entry into the eye, light will first encounter the cornea, which is a transparent body

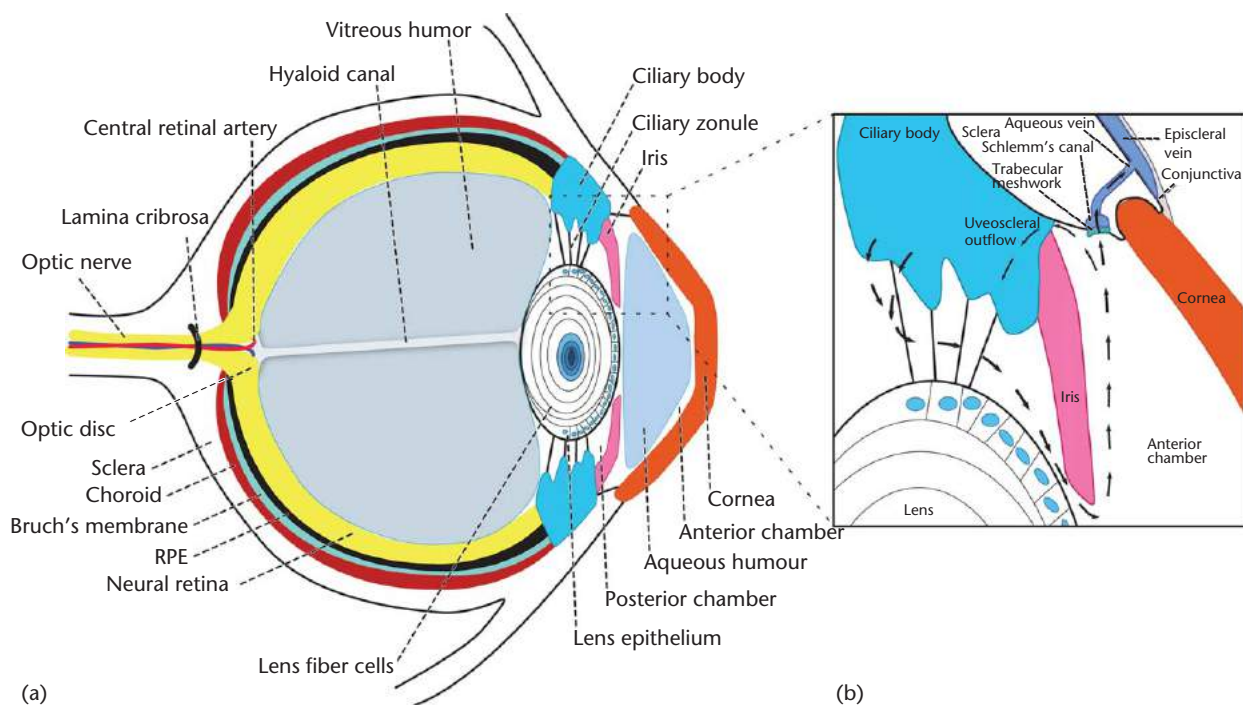


Figure 1 Schematic of a vertebrate eye. (a) Basic structures of the vertebrate eye have been colour coded. (b) Magnification of the anterior part of the eye, depicting the structures involved in aqueous humour circulation.

consisting of an epithelium, a thick fibrous structure made up of connective tissue and extracellular matrix, a homogeneous elastic lamina and a single layer of endothelial cells. The cornea protects the rest of the eye from germs, dust and other harmful matter. It filters the most damaging ultraviolet wavelengths of the sun's rays and is also the primary contributor in the focusing of light onto the retina. The cornea has a greater refractive index than that of air so that when light hits its surface, it slows down. The light beam's path is then bent and converges towards the centre of the eye, thus, reducing the image that has been refracted. Like most transparent media, the cornea bends light with minimal scattering, which allows a light beam to continue passage in its original direction. All of these intrinsic properties contribute to the formation of a discernible image and are made possible by the spatial uniformity of its cells, which contributes to its acuity of light transmission (Oyster, 1999).

The aqueous humour

Positioned between the cornea and the lens, the aqueous humour is formed by the ciliary epithelium of the ciliary body that is located in the posterior chamber. The aqueous humour is constantly replenished, as it flows through the pupil and fills the anterior chamber. From there, a large portion of aqueous humour leaves the eye through the trabecular meshwork into Schlemm's canal and the episcleral venous system. The remainder drains via the uveoscleral route by simple percolation through the

interstitial tissue spaces of the ciliary muscle, continuing to pass into the suprachoroid and leaving through the sclera. The constant flow of aqueous humour into the eye regulates its ocular pressure so that the eye's optical properties can be maintained. This circulating flow also delivers oxygen and nutrients to the anterior region of the eye and removes metabolic waste products from its anterior chamber, as the avascular region near the lens and cornea cannot rely on capillaries to serve this function (To *et al.*, 2002). The aqueous humour also assumes a role in the local immune response by dispensing ascorbate, an antioxidant concentrated by the ciliary epithelium, throughout the eye (Civan, 2008; **Figure 1b**).

The pupil and iris

Once light has passed the aqueous humour, it moves onto the next group of structures; the iris and pupil. These two structures regulate the amount of light passing through the system. The iris consists of a pigmented sheet of cells that lies directly in front of the lens and has the ability to restrict and dilate with the aid of sphincter and dilator muscles, respectively. This contraction and dilation regulates the pupil – the aperture of the eye. In cases of abundant light, the iris decreases the pupillary aperture with the aid of the sphincter muscles and tries to avoid the admittance of too much light, which would eventually result in the processing of a muddled blur. The opposite is true when light is lacking, and the pupil becomes greatly dilated in an attempt

to gather as many photons of light as possible for imaging (Bruce *et al.*, 1996).

The lens

Once the optimal amount of light has entered the eye through the pupil, it encounters the lens. The lens, composed of a lens epithelium layer covering a mass of lens fibres, is primarily made up of proteins called crystallins, which further refine the light from the cornea (Land and Fernald, 1992). Like the cornea, the molecules of the lens are densely packed and uniformly spaced – characteristics required for its transparency. The lens has an inherently greater index of refraction than the cornea due to its surrounding environment – namely the aqueous and vitreous humours which also have relatively high indexes of refraction. Thus, the index of the lens must be even higher if it is to focus the image further and contribute to the optical system. Though the lens has an inherent refractive index, it also has the ability to change its degree of refraction with the aid of ciliary muscles and ciliary zonular fibres in the process of accommodation. When the eye views an object at a distance beyond 6 m (20 feet), the lens is forced to assume a flattened shape because the ciliary muscles and the zonular fibres holding it in place will pull it outward. When the eye focuses on an object within 6 m, the lens is forced into a bulging shape by the contraction of the ciliary muscles accompanied with a reduced tension in the zonular fibres. This results in an increase in the lens' optic power which brings the focal point closer, effectively creating a clear image of an object that is within 6 m of the viewer (Charman, 2008). **See also:** [Crystallins](#)

The ciliary body

The circumferential tissue surrounding the lens is the ciliary body, which is composed of ciliary muscle, ciliary zonule and the ciliary epithelium. The ciliary zonule consists of a series of thin, peripheral ligaments that suspend and hold the lens in place (also known as suspensory ligaments). A double-layered ciliary epithelium coats the ciliary body and has several important ocular functions, including the secretion of aqueous humour, as well as the synthesis and attachment of the suspensory zonule fibres. The inner layer of the ciliary epithelium is not pigmented and is continuous with neural retinal tissue. The ciliary epithelium's outer layer is highly pigmented and is continuous with the retinal pigmented epithelium (RPE). There are reports that have shown the presence of quiescent stem cells in the pigmented ciliary epithelium of adult mammals. These cells have been induced to proliferate and express markers of multiple retinal cell types *in vitro* and *in vivo* (Coles *et al.*, 2004; Zhao *et al.*, 2005; Nickerson *et al.*, 2007; Inoue *et al.*, 2010). However, other studies question the 'stem cell' identity of these cells and their possible use for developing stem cell therapy to treat retinal degenerative diseases in humans (Cicero *et al.*, 2009).

The vitreous humour

Occupying the cavity between the lens and the retina, the vitreous humour accounts for approximately two-thirds the volume of the entire eye. Composed 99% of water, with a small amount of collagen, the vitreous humour is clear and avascular, with a gel-like consistency. It serves as a transparent structure through which light, refracted by the lens and cornea, can pass; and it provides support for the delicate lens. The vitreous humour is also in contact with the retina, though it only adheres to it at the optic nerve disc; it helps hold the retina in place by exerting a pressure on it against the choroid. Additionally, the vitreous humour is attached to the dorsal side of the lens and the ora serrata, the point at which the retina ends anteriorly. Once the vitreous humour has developed and reached its full size, it is stagnant (Lens, 2008). As the eye ages, the gelatinous vitreous shrinks, and more fluid is secreted to fill the vacancy, effectively diluting the vitreous humour in a process termed vitreous syneresis. If the vitreous is detached from the eye's posterior region during this process, the occurrence of floaters in vision is likely (Yonemoto *et al.*, 1996). Aging, along with other retinal disorders can also cause the development of small holes in places where the retina has thinned. Vitreous humour can leak through those holes and cause retinal detachment from the underlying support tissue, which is detrimental to visual acuity and can lead to blindness (Ghazi and Green, 2002).

The Retina as a Part of the Central Nervous System

A viewer would never perceive an image if it were not for the retina; it is the light-processing centre of the eye, where light signals are transformed into neural signals that can be processed by the brain. These neural cells are remarkably similar to those of the brain, supporting the common assertion that the visual system is an outgrowth of the central nervous system.

Organisation of the retina into the different cell and synaptic layers

The retina can be divided into many distinguishable layers. The outermost layer of the neural retina is the photoreceptor layer which contributes to the vertical transfer of signals in the retina. This layer consists of two types of photoreceptors – rods and cones – which are responsible for receiving and transforming photons of light to electrochemical impulses. The nuclei of these photoreceptor cells reside in the outer nuclear layer (ONL), projecting from there to the outer plexiform layer (OPL) and forming synapses with the dendrites of bipolar cells. This plexiform layer, thus, constitutes the first synaptic layer. Like the outer layers, the inner layers can also be divided into nuclear or plexiform layers. The inner nuclear layer (INL) contains the nuclei of bipolar cells, horizontal cells and the

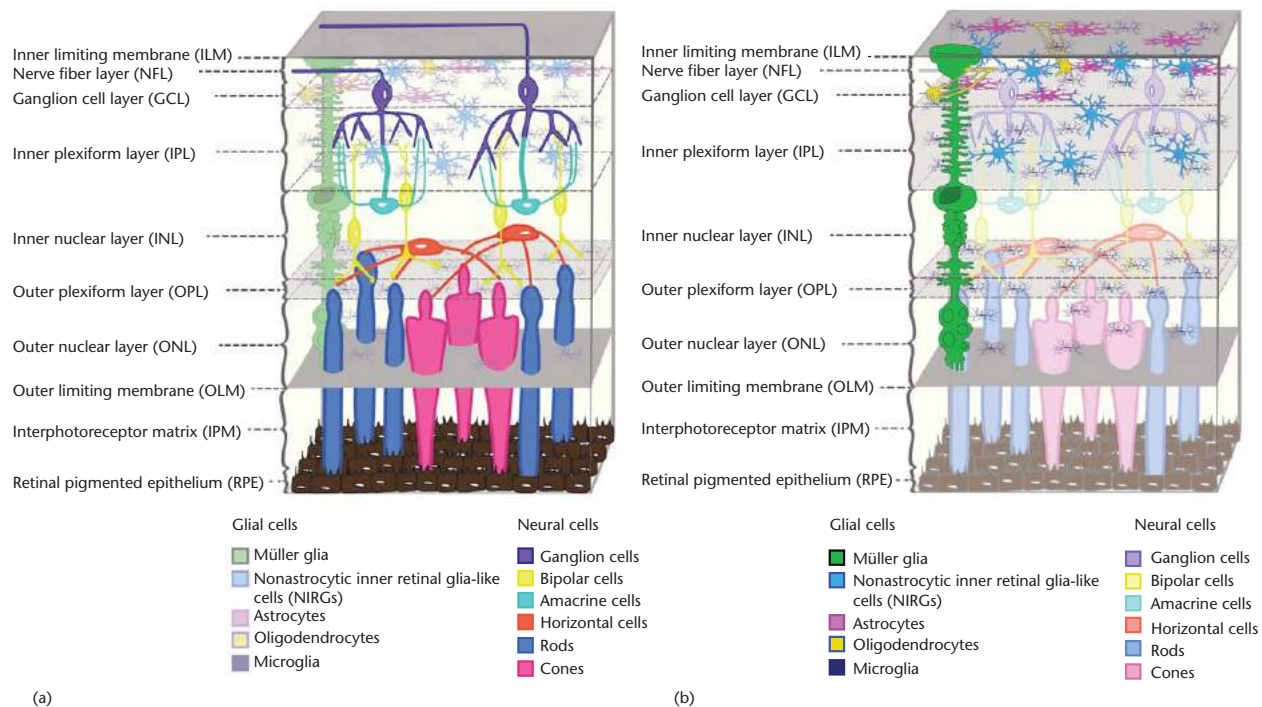


Figure 2 Schematic view of the organisation of neurons and supportive glial cells in the vertebrate retina. (a) Organisation of retinal neurons within the retina. Six types of neurons are present in the vertebrate retina including rod and cone photoreceptors, bipolar, horizontal, amacrine and ganglion cells. (b) Organisation of retinal glial cells within the retina. Five glial cell types have been found in the vertebrate retina. Astrocytes are present in vascular retinas whereas oligodendrocytes are predominantly present in avascular retinas.

majority of amacrine cells, as well as the cell bodies of supportive glial cells. The INL borders the inner plexiform layer (IPL), where vertical communication between the bipolar cells and ganglion cells takes place, thus making up the second synaptic contact layer. The next layer, the ganglion cell layer (GCL), contains the cell bodies of the ganglion cells. The dendrites of these ganglion cells extend into the IPL layer, whereas their axons extend in the opposite direction into the nerve fibre layer (NFL). In this layer, all of the ganglion cell axons travel towards the optic disc (Purves *et al.*, 1997; **Figure 2a**).

Six types of neurons in the retina

Now that the groundwork of the retina has been laid out, the cells already mentioned can be discussed further, starting with the six different kinds of neurons in the retina. The first three neurons are involved in the vertical transmission of information through the retina. They are the rod and cone photoreceptors located in the ONL and bipolar cells located in the INL.

Rods and cones

Of the 130 million photoreceptors present in the human eye, approximately 120 million are long, cylindrical structures known as rods. Rods are extremely sensitive to light,

but they only transmit shades of grey to the brain. Cones, on the other hand, are thicker, shorter cells which are able to register fine detail and colour, provided they receive enough light (Kolb, 2003). Phototransduction is possible through the use of photopigments contained within the rods and cones. Both cells contain the light-sensitive protein opsin. Rods possess one type of opsin, which binds to a straight chain of vitamin A, and assumes a bent position. While in this conformation, the complex is called rhodopsin (Palczewski, 2012). When even a single photon of light strikes rhodopsin, the energy absorbed causes the bent vitamin A chain to snap back into its original, straightened form. This occurrence, consequently, disrupts the electrical field within the photoreceptor, initiating an electrical impulse that begins its journey to the brain. The cones, however, possess three different types of opsins which are capable of binding to vitamin A, forming three classes of photopsins. Each class of photopsins reacts to different ranges of light frequency and is, thus, responsible for the creation of one of the three primary colours (red, blue or green), as interpreted by the brain (Merbs and Nathans, 1992). However, as mentioned earlier, cones are less sensitive to low intensities of light, and require a very specific wavelength of light to initiate an electrical impulse. This is why our daylight environment is full of brilliant colours, whereas our rod-dominated night vision produces various shades of grey. Because colours are merely the results of

biochemical interpretations of various wavelengths of light whose identities are dependant on the biochemical make-up of the particular organism processing this information, the world is, essentially, colourless (Conway, 2009; Palczewski, 2012).

Bipolar cells

The next set of neurons which propagate the vertical, or direct, communication pathway is the bipolar cells. As stated in 'Organization of the retina into the different cell and synaptic layers', bipolar cell bodies reside in the INL whereas their dendrites receive signals from photoreceptors at the first synaptic junction. On the opposite end of their cell bodies, signals travel through the bipolar cells' axons to the synaptic cleft formed between their axon terminals and the dendrites of the neighbouring vertical ganglion cells (Wan and Heidelberger, 2011).

Lateral neurons: horizontal and amacrine cells

The electrical impulses running through the vertical neurons are not completely independent of one another because most are linked by lateral neurons. One type of lateral neurons is the horizontal cell, which is found in the INL of the retina. Horizontal cells are commonly linked to more than one photoreceptor, so subsequent bipolar cells receive signals from more than one photoreceptor. This pathway would seem to lessen visual acuity, but in most cases, it serves to increase perceived contrast (Fahrenfort *et al.*, 2005). Amacrine cells are the other type of lateral neurons present in the retina. These cells form links between vertical pathway neurons in the inner layers, and sometimes the GCL of the retina. Their effects are not entirely clear, but they are thought to contribute to better contrast, as well (Kolb, 1997).

Retinal ganglion cells and output from the retina

The last neurons of the network to receive input are the retinal ganglion cells. When activated by an incoming signal, the ganglion cells produce an action potential that begins its journey down the cells' axons. The axons converge, forming the optic nerve, which serves as a highway for electrical signals en route to the brain. Interestingly, there is also a rare type of ganglion cell in the mammalian retina termed the photosensitive retinal ganglion cell, which has the ability to detect light directly. These cells represent a small subset (~1–3%) of the retinal ganglion cell population. However, they play a major role in synchronising circadian rhythms with the 24 h light–dark cycle, primarily supplying information on the lengths of day and night (Foster *et al.*, 1991). **See also:** [Visual System](#)

The Fovea and Macula

The fovea and macula are the most sensitive part of the retina, providing for sharp central vision. The cones of the eye are responsible for discerning minute details. The highest concentration of cones is found in the fovea, a small pit at the centre of the retina, with a diameter of approximately 1.0 mm in the human eye. Although cones are densely packed in the fovea, no rods are present in this area. Owing to its composition and resolving capabilities, the fovea is an obvious target for light as it enters the eye. The cornea and lens make it possible to focus light onto this small area in order to produce the clearest, most detailed image. Surrounding the fovea in the central retina, is the macula – a highly pigmented, yellow spot with a diameter of 5 mm. This structure lacks many of the common retinal layers, the only stratifications present being the RPE, the ONL and a bit of the OPL (Kolb, 2011). The yellow pigment of the macula is derived from two xanthophylls, lutein and zeaxanthin. These macular photopigments protect the macula and fovea by filtering out short wavelengths of light. Their antioxidant capabilities also serve to protect the outer retina, RPE and choriocapillaris from oxidative damage (Whitehead *et al.*, 2006).

Supportive Cells/Tissues of the Neural Retina

Glial cells in retina

Glial cells are the nervous system's support cells. They provide structural support and protection for neurons by holding them in place and isolating them from one another. Additionally, they supply neurons with nutrients and oxygen, and remove the debris of dead neurons. Multiple types of glial cells have been found in the retinas of different species of vertebrates, including Müller glia, microglia, astrocytes, oligodendrocytes and nonastrocytic inner retinal glial-like cells. These glial cell types are described in detail below ([Figure 2b](#)).

Müller glia

Müller glia cells are the principal support cells of retinal neurons. Their cell bodies sit in the INL and project their dendrites in either direction to the outer limiting membrane (OLM) or to the inner limiting membrane (ILM), forming architectural structures to other neurons. Müller glia cells entwine their dendrites with the cell bodies of neurons in the nuclear layers and envelop groups of neural processes in the plexiform layers, allowing for the direct contact of retinal neuronal processes at their synapses. Müller glia can also interact with other glia cells, namely astrocytes, to modulate neuronal input (Newman, 2004). Müller glia cells in the adult retina are also a source of residential stem cells, which retain multipotency but have limited capabilities. However, these cells can be induced to give rise to rod

photoreceptors in the mammalian retina. In fish, these cells are able to regenerate all neuroretinal cell types (Giannelli *et al.*, 2011; Barbosa-Sabanero *et al.*, 2012).

Microglia

Originating from the haematopoietic lineage, microglia enter the retina early in development. During late embryonic stages, they migrate to the retina via the retinal vasculature and populate the ONL, OPL, IPL, GCL and NFL layers of the retina. Microglia are involved in initiating host defence against invading microorganisms, in immunoregulation, as well as in tissue repair. They can be stimulated to behave like macrophages after injury and during neurodegeneration, with the ability to phagocytise the degenerating neurons, thus facilitating regenerative processes. In autoimmune diseases, microglia not only augment immune responses, but also limit subsequent inflammation (Bodeutsch and Thanos, 2000; Chen *et al.*, 2002).

Astrocytes

Astrocytes are usually present in the retinas of animal species with vascular retinas, such as those of mice and monkeys (Fischer *et al.*, 2010b). They are the primary facilitators of retinal angiogenesis, secreting vascular endothelial growth factor to stimulate new blood vessel growth. As the blood vessels form, astrocytes migrate into the retina from the optic nerve, leading the tips of the growing vessels. Functionally active in the GCL and NFL layers, astrocytes are considered special glia for the axons of ganglion cells. Together with Müller glia cells and blood vessels, they form the glia limitans, setting up the boundary between the retina and the vitreous humour, termed the ILM (Büssow, 1980; Zhang and Stone, 1997). Although astrocytes are part of the neural retina, they do not communicate using electrical impulses; instead, they use specialised microdomains – lamellipodia and filopodia – which are fine cellular extensions. Their unique structural composition affords astrocytes motility, and allows for highly dynamic interactions with their surroundings. Astrocytes and Müller glia are chemically and electrically coupled by gap junctions, and therefore, astrocytes can modulate synaptic transmission and act as ‘the middle men’ between synaptic and nonsynaptic cellular communication in their discrete microdomains (Zahs and Newman, 1997; Newman, 2004; Volterra and Meldolesi, 2005).

Oligodendrocytes

Both oligodendrocytes and astrocytes are derived from a common multipotent brain progenitor cell. These progenitor cells migrate to the optic nerve and respond to local signals from the retinal ganglion cell axons to differentiate into either oligodendrocytes or astrocytes (Pressmar *et al.*, 2001; Gao and Miller, 2006; Rompani and Cepko, 2010). Along with astrocytes and microglia, oligodendrocytes play a critical role in supporting the optic nerve, which consists of the axons of ganglion cells (Butt *et al.*, 2004).

They provide myelination for adjacent ganglion cell axons. The production of a layered myelin sheath around a nerve axon is critical for the rapid conduction of electrical nerve communication (Carlson, 2009). Even though oligodendrocytes are found in the optic nerve of all animal species, only animals with avascular retinas like those of guinea pigs and chickens will have oligodendrocytes in the NFL (Wyse and Spira, 1981; Fischer *et al.*, 2010b). In humans, oligodendrocytes begin myelinating the optic nerve throughout fetal development, but they balk at the lamina cribrosa (Oyster, 1999). Oligodendrocyte dysfunction in humans is usually present in diseases such as optic neuropathy and diabetic retinopathy (Goldenberg-Cohen *et al.*, 2005; Fernandez *et al.*, 2012).

Nonastrocytic inner retinal glia-like cells (NIRG)

A novel retinal cell type, recently discovered in the chicken eye, has been termed NIRG cell (Fischer *et al.*, 2010a). These NIRG cells have also been found in non-human primates, in addition to canines (Fischer *et al.*, 2010b). Having migrated into the retina from the optic nerve, NIRG cells are dispersed within in the IPL and GCL, acting closely with the retina’s other glial cells. There is another report describing similar novel glial cells in the chick that were termed diacytes. These cells share many characteristics of the NIRG cells (Rompani and Cepko, 2010). Fischer *et al.* (2010b) has suggested that these cells may be the same as NIRGs, however this needs to be further proven. It has been reported that the NIRG cells, together with microglia, facilitate the cell death of both neurons and Müller glia in the retina in response to excitotoxic damage (Fischer *et al.*, 2010a).

The retinal pigmented epithelium (RPE)

The RPE is a monolayer of heavily pigmented epithelial cells which borders the neural retina. It is characterised by its tight junctions, forming the blood–retinal barrier. RPE cells do not contribute directly to the transformation and transduction of information in the retina, but they do provide supportive functions for the adjacent layer of photoreceptor cells by absorbing scattered light rays and allowing essential nutrients through. The RPE regulates transportation of ions, water, growth factors and nutrients such as glucose and amino acids to photoreceptors of the neural retina. The RPE is also involved in the maintenance of retinal cell adhesion by supporting the interphotoreceptor matrix (IPM). This extracellular matrix is bound to the OLM and the apical membrane of the RPE (membrane bordering the photoreceptors). The IPM is critical for the metabolic exchanges between the photoreceptors and the RPE. Its bonding properties and viscosity are regulated by the RPE, which tightly controls the ionic environment in that region. Additionally, RPE cells are essential in the regeneration of photopigments, because they uptake, store and reisomerise vitamin A, which is

necessary in the synthesis and proper functioning of the photopigments rhodopsin and photopsin. The RPE also phagocytises the tips of the outer segment of photoreceptors on a regular basis, digesting and recycling its components. Melanin, the pigment present in the RPE, reduces the scatter of light to the photoreceptors, shielding them from excessive light exposure (Marmor and Wolfensberger, 1998). Recently, a population of stem cells was also identified in the RPE, and these cells were shown to possess the capacity to become neuroretinal and mesenchymal cells *in vitro* (Salero *et al.*, 2012). As a matter of fact, in some salamanders such as newts, the RPE is capable of regenerating the entire retina (Tsonis and Del Rio-Tsonis, 2004; Barbosa-Sabanero *et al.*, 2012). **See also:** [Regeneration of the Vertebrate Lens and Other Eye Structures](#)

The optic nerve and optic disc

The optic nerve serves as the pathway connecting the retina to the brain's visual processing centre. The area where the optic nerve is crossing through the posterior fundus of the eye is called the optic disc, also termed the optic nerve head. Approximately 1.5 mm in diameter, the optic disc is where the nerve fibres leave the eye en route to the brain; it is also where the central retinal vein exits the eye and the central retinal artery enters. Because the optic disc contains no photoreceptors, it creates a blind spot on the retina (Lens, 2008).

The choroid

The choroid, also known as the choroidea or choroid coat, is the vascular layer of the eye containing connective tissue that surrounds the globe. In humans, it is thickest at the extreme posterior eye (0.2 mm), and thinnest in the anterior surface (0.1 mm). Located between the retina and sclera, the choroid is separated from retinal nervous tissue by two structures: Bruch's membrane and the RPE. Bruch's membrane, the basement membrane anterior to the choroidal vasculature, serves to mediate the passage of nutrients into the retina, and filter out retinal debris seeking an outlet through the choroid vessels. The choroid provides the greatest blood flow to the retina (65–85% of total blood supply), allowing it to adequately supply oxygen and nutrients to the photoreceptors in the outer layers of the retina (Henkind *et al.*, 1979; Lens, 2008).

The central retinal artery

The central retinal artery accounts for the remaining 20–30% of blood supply to the mammalian retina which is not covered by the choroid vessels, providing nourishment for the inner retinal layers. Emerging from the optic nerve, the central retinal artery then branches into three layers of capillary networks in the retina, the radial peripapillary capillaries (RPCs), the inner capillaries and the outer capillaries. The RPCs are the most superficial layer of capillaries which occupy the inner part of the nerve fibre

layer. The inner capillaries lie in the GCL layer beneath the RPCs, and the outer capillary network spans from the IPL to the OPL. These three sets of capillaries flow in and out of each other throughout the retina and finally converge again as they exit the eye through the central retinal vein at the optic disc (Zhang, 1994). The hyaloid canal runs from the optic disc to the surface on the back of the lens. It contains a prolonged branch of the central retinal artery running along its length to facilitate the transport of nutrients to the lens during fetal development. This canal becomes avascular and filled with lymph in the adult eye (Oyster, 1999).

The sclera

The sclera is one of the most palpable parts of the human eye – the white in contrast with the coloured iris. In non-human mammals, the visible part of the sclera matches the colour of the iris, so the white part does not normally show. The sclera is composed of collagen and elastic fibres, which provide a tough, opaque protective posterior coating for the eye. The sclera and cornea are actually composed of the same fibrous tissue, only differing in their degrees of hydration. If the tissue is more dehydrated, it will be more transparent like the cornea, whose dehydration is maintained by the corneal endothelium; if the fibrous tissue is more hydrated, it will be opaque like the sclera (Lens, 2008). The region where the sclera comes into contact with the cornea is called the corneal limbus. Stem cells required for the repair of damage to the corneal epithelium have been found in the basal membrane of the corneal limbus (Daniels *et al.*, 2001). Because the sclera is largely an avascular structure, it must, therefore, derive its nutrients from the episclera and the choroid (Lens, 2008).

Summary

Following the path of light through the vertebrate eye, we have journeyed through the different components that make the eye function as a perfect light-gathering and information-processing organ. The light is first refracted, adjusted, and focused onto the retina via the collaborative efforts of the cornea, iris, pupil, lens, aqueous and vitreous humour, ensuring that the right amount of light from the environment is captured and focused onto the fovea and macula, the most light-sensitive area on the retina responsible for the fine details of images. Once the light is focused onto the retina, the light signal is converted into electrochemical impulses via the teamwork of neurons and glial cells within the retina. The signal is then sent to the processing centre of the brain via the highway: the optic nerve. All other supportive components of the eye including the RPE, the choroid, the central retinal artery and the sclera are equally important for the proper functioning of the eye by providing protection, supplying oxygen and nutrients, as well as cleaning up its waste. The functions of the eye represent a symphony of activity that has been perfected over millions of years, resulting in each organism's detector of light.

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