

2 Background

Visual impairment can markedly reduce health and wellbeing. It can affect a person's ability to perform everyday activities such as reading or watching television, as well as their mobility (increasing the risk of falls and injury), their ability to drive and their ability to work. These effects reduce the person's independence and are often accompanied by isolation, depression and poorer social relationships.

2.1 Visual impairment and blindness in Australia

The most prevalent causes of vision loss and blindness in Australia, as in other developed countries, are the age-related degenerative eye diseases such as macular degeneration, glaucoma and cataract. In 2004, 9.4% of the 4.7 million Australians aged 55 or more were visually impaired. Cataract was the most prevalent eye disease (31%), followed by age-related macular degeneration (AMD) (3.1%), diabetic retinopathy (2.8%) and glaucoma (2.3%) (AIHW 2005). Together with uncorrected refractive error, these diseases contribute to more than 90% of visual impairment in this age group. If refractive error (which can be corrected by eyewear) is excluded, cataract is the primary cause of 40% of cases of vision loss in older Australians and AMD the primary cause of 28%.

The leading causes of blindness among Australians aged 55 or more are AMD (50%), glaucoma (16%) and cataract (12%).

Some vision problems among older Australians are acquired early in life (eg retinitis pigmentosa and eye trauma), but at a population level their prevalence is small compared with vision problems associated with ageing.

Since prevalence rates of eye disease are strongly age-related and Australia has an ageing population, the number of people with visual impairment may well increase nationally. This will have significant economic implications and affect the provision of health and welfare services.

2.2 How the eye works

2.2.1 Structure of the eye

Figure 2.1 shows the main structures of the eye. Each structure (in bolded italics) is explained below.

To maintain its shape, the eye is kept firm by a clear fluid flowing continuously in and out of the ***anterior chamber***, which nourishes nearby tissues with oxygen, sugars and other nutrients. Circulating around the structures inside the eye, the fluid leaves the chamber at the open angle where the ***cornea*** and ***iris*** meet. When the fluid reaches the angle, it flows through a spongy meshwork, like a drain, and leaves the eye. Drainage is against resistance, so the eye's pressure is kept higher than air pressure but lower than blood pressure.

The **lens** is a clear structure at the front of the eye that helps to focus light, or an image, on the **retina**. The retina is a thin layer of neural tissue that lines the back of the eye. In a normal eye, light passes through the transparent lens to the retina. The lens must be clear for the retina to receive a sharp image.

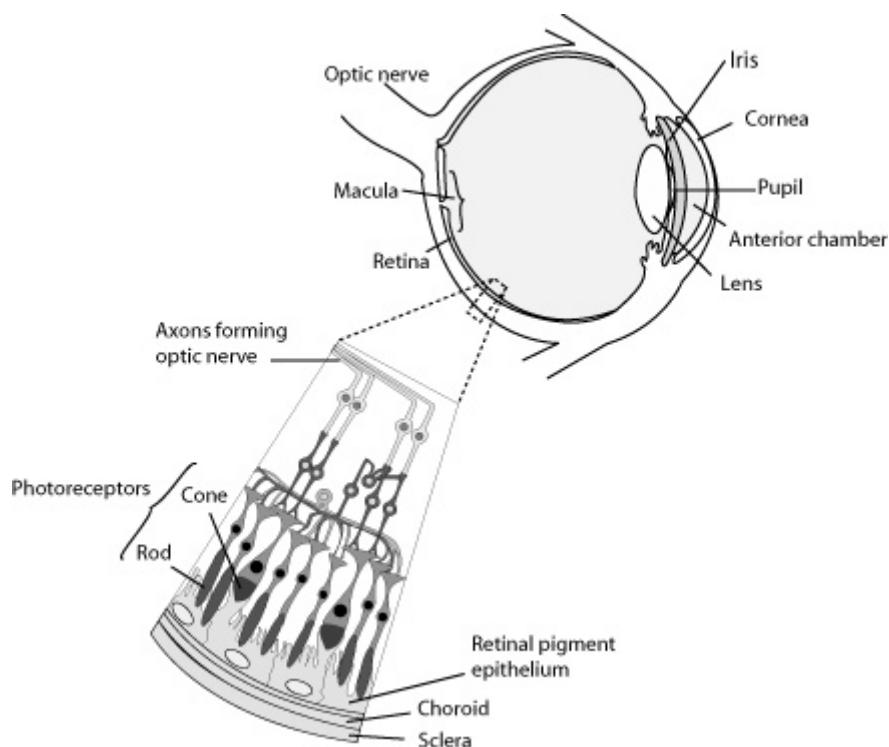


Figure 2.1 Anatomy of the eye and retina

The **iris** is the coloured part of the eye that helps regulate the amount of light entering the eye. When there is bright light, the iris closes the pupil to let in less light; when there is low light, the iris opens up the pupil to let in more light.

The **retinal pigment epithelium** (RPE) is the layer between the retina and the blood vessels underneath, which are known as the **choroid**. The RPE passes oxygen, sugar and other nutrients up to the retina and moves waste products (such as cellular debris from the tips of the photoreceptors as they renew themselves) down to the choroid.

2,2,2 Interactions between the eye and the brain

Once light reaches the retina, the light-sensing cells (**photoreceptors**) convert light into electrical impulses. Photoreceptor cells are either **rods** or **cones**. Rods are concentrated along the outer perimeter of the retina; they help us to see images in our peripheral vision and also to see in dark and dimly lit environments. Cones are concentrated in the **macula**, the centre of the retina, allowing us to see fine visual detail in the centre of our vision; they also allow us to perceive colour. Together, the photoreceptors convert light into electrical impulses that are passed through the rest of the retina, through the **optic nerve** to the brain. The visual centres in the brain interpret the information received from the retina, enabling us to see.

2.2.3 How we focus on an object

The eye can change its optical power to maintain a clear image (focus) on an object as it moves towards and away from the retina. The main focusing ability of the eye is due to the difference in refractive index between air and the curved cornea. The cornea cannot change its curvature; however, the curvature of the lens can change, and this process is called *accommodation*.

Normally, parallel rays from distant objects will converge onto the retina. If an object is moved closer to the eye, and if the lens does not change its curvature, then the sharp image will remain behind the retina and our brain will only be able to detect a blurry image. If the lens changes its curvature (becoming thicker) then the light rays will converge on the retina, and the image will be clear (see Figure 2.2).

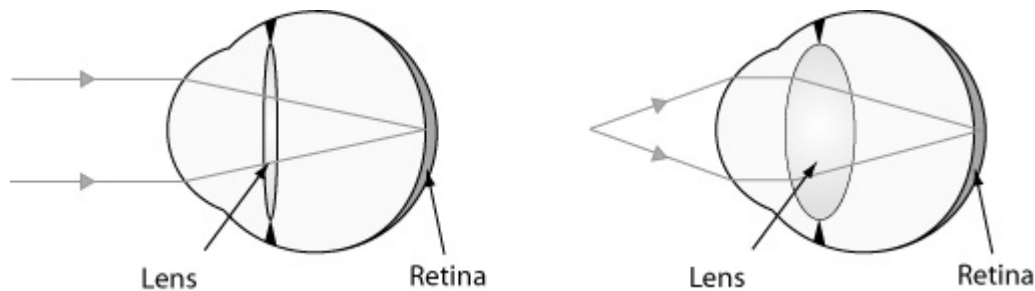


Figure 2.2 Accommodation

2.3 Eye diseases

A number of things can go wrong in any of the structures of the eye, causing visual impairment and blindness. Many of these deteriorations are due to ageing. The main visual disorders are described below.

2.3.1 Glaucoma

Glaucoma is a group of diseases of the optic nerve that result in loss of vision or blindness. The optic nerve is gradually destroyed, usually due to excessively high intraocular pressure, known as ocular hypertension (OHT).

Open-angle glaucoma (OAG) is the most common form of glaucoma. It occurs when the fluid in the anterior chamber reaches the angle between the cornea and iris, and passes too slowly through the meshwork drain. As the fluid builds up, the pressure inside the eye rises to a level that may damage the optic nerve. Different people's eyes can withstand different levels of intraocular pressure, and a diagnosis of glaucoma requires damage to the optic nerve rather than OHT alone.

Glaucoma can also develop without increased eye pressure (called low-tension or normal-tension glaucoma). Causes include poor blood supply to the optic nerve fibres, a weakness in the optic nerve structure or a problem with the optic nerve fibres.

2.3.2 Cataract

Cataracts are a clouding of the lens, resulting in a blurred image. The lens is made of mostly water and protein, arranged in a way that keeps the lens clear and allows light to pass through. As we age, some of the protein may clump together and start to cloud a small area of the lens, resulting in a cataract that reduces the amount of light reaching the retina. Over time, the cataract may slowly grow larger and cloud more of the lens, making vision gradually duller or more blurred.

There are three main types of cataract:

- *nuclear cataracts* are the most common type, so named because they occur in the centre of the lens
- *cortical cataracts* start in the cortex (periphery) of the lens and gradually extend to the centre of the lens
- *subcapsular cataracts* are those in which the opacities are concentrated beneath or within the capsule of the lens.

Cataract development is part of the ageing process. Hence, although lifestyle changes may reduce the rate of development for some people, cataracts cannot be prevented. However, surgery can correct the condition.

2.3.3 Age-related macular degeneration

In AMD, clumps of yellowish material (known as drusen) gradually accumulate within and beneath the RPE. The RPE cells may die and therefore no longer support the photoreceptors, which then cannot function, resulting in loss of vision in that part of the retina. If the photoreceptors in the macula are affected, this can seriously impair fine visual skills; this situation is sometimes referred to as 'dry' macular degeneration (or central, geographic atrophy), and is the most common form of AMD.

In about 10% of cases, dry AMD progresses to a more advanced and damaging form of the eye disease known as wet macular degeneration (or neovascular AMD). New blood vessels grow beneath the retina to supply more nutrients and oxygen to the retina. However, often these blood vessels are in areas where they are not supposed to be; for example, in the macula. Bleeding, leaking and scarring from these blood vessels affect the photoreceptors and impair vision.

2.3.4 Diabetic retinopathy

Diabetic retinopathy is a common complication of diabetes. Poor glucose control during diabetes affects the tiny blood vessels of the retina. The arteries become weakened and leak blood, leading to swelling or oedema in the retina and decreased vision.

As diabetes progresses, circulation problems can also deprive the retina of oxygen. New, fragile, vessels develop; however, these are susceptible to bleeding and the blood may leak into the retina and vitreous, causing spots or floaters, along with decreased vision. If abnormal blood vessel growth continues, scar tissue formation may cause retinal detachment and glaucoma may also develop.

2.3.5 Retinitis pigmentosa

Retinitis pigmentosa refers to the group of genetic eye diseases that causes degeneration of photoreceptor cells in the retina. As these cells degenerate and die, patients experience progressive vision loss. The condition is diagnosed by using electroretinography to document progressive loss in photoreceptor function.

2.3.6 Pterygium

A pterygium is a noncancerous growth of the clear, thin tissue that overlies the white part of the eye (the conjunctiva). The condition may affect one or both eyes. Although the cause of pterygia is unknown, people who work outdoors and are excessively exposed to sunlight and wind more frequently develop pterygia than people who work indoors. Pterygia present as a painless, raised area of white tissues, with blood vessels on the inner or outer edge of the cornea. No treatment is usually required unless the pterygia begins to obstruct vision, and surgical removal of the pterygium usually has good results.

2.3.7 Ocular surface neoplasia

Ocular surface neoplasia is term used to describe various dysplasias, carcinoma in situ and squamous cell carcinoma of the ocular surface epithelium (conjunctiva and cornea).

2.4 Eye disorders

2.4.1 Refractive errors (myopia, hyperopia, presbyopia, astigmatism)

The term 'refractive error' encompasses myopia (near-sightedness or short-sightedness), hyperopia (far-sightedness or long-sightedness), presbyopia and astigmatism. Most people have one or more of these disorders, which are routinely corrected with glasses, contact lenses or surgery. The cornea, the lens and the axial length (the length of the eye) all contribute to the eye's refractive power. When each eye has a different refractive error, this is known as anisometropia.

Myopia

Myopia occurs when images are formed in front of the retina because the eye is relatively too long or the refractive powers of the cornea and lens of the eye are relatively too strong. The result is a blurred image.

Very high levels of myopia are associated other eye conditions such as cataracts, glaucoma and retinal detachment, which can lead to low vision and even legal blindness.

Hyperopia

Hyperopia occurs when images are formed behind the retina because the eye is relatively too short or the refractive powers of the cornea and lens of the eye are relatively too weak. The result is a blurred image.

Astigmatism

Astigmatism results from the cornea (or the lens) not being ‘perfectly’ round. A cornea or lens with such smooth surface curvature refracts all incoming light the same way and makes a sharply focused image on the retina. However, if your cornea or lens is not evenly and smoothly curved this causes a refractive error, resulting in a blurred image. Astigmatism of some degree is present in approximately 30–40% of people who wear glasses or contact lenses.

Most investigations look at refractive error in the central part of the retina; however, there have been some studies that have shown that peripheral refractive errors can exist in eyes that have little central astigmatism.

Presbyopia

As we age, the lens gradually hardens and becomes less pliable, making it increasingly difficult to focus on near objects. By about 45 years of age, most people require reading correction. Many people assume that this correction is for hyperopia; however, the condition is called presbyopia.

2.4.2 Amblyopia

Amblyopia, also known as ‘lazy eye’, is the term used when vision in one eye is reduced because the pathways from the eye to the visual cortex of the brain do not develop or mature properly. The eye itself looks normal, but is not used normally because the brain favours the other eye. Amblyopia may be caused when the position of the two eyes is not balanced, or when one eye is more near-sighted, far-sighted or astigmatic than the other eye.

2.5 Eye injury

Eye injury can occur in a number of circumstances; for example, in the workplace (eg welding), around the home, or while playing sport (eg football, racquet ball) or other recreational activities (eg paintball). Examples of common causes of eye injury include:

- chemical burns, including alkali, acid or irritants — chemicals entering the eye can cause damage to the cornea, but occasionally can penetrate the internal eye structures of the eye, including the lens
- corneal abrasions — a scrape or scratch on the cornea
- hyphema — bleeding between the cornea and iris
- open globe injury — a full-thickness wound of the outer membrane of the eye involving the sclera or cornea
- closed globe injury — an injury where there is no full-thickness wound of the eye
- foreign objects entering the eye — penetrating injuries are caused by an object physically piercing the eye whereas ruptures occur from blunt force or nonpenetrating impact which, through distortion of the globe, results in a full-thickness laceration.

2.6 Eye infections

2.6.1 General

Eye infections can be caused by bacterial, viral or other microbiological agents. Infections can affect the eyelids, the cornea and even the optic nerve. Common examples include:

- conjunctivitis — infection or inflammation of the conjunctiva, the thin, transparent tissue that covers the outer surface of the eye
- styes — bacterial infections that lead to the obstruction of oil-producing glands around the eyelashes or eyelids, causing small bumps on eyelids
- keratitis — an infection of the cornea that can be caused by *Acanthamoeba* (a microscopic, waterborne parasite) or the bacteria *Staphylococcus aureus* and *Pseudomonas aeruginosa*
- toxoplasmosis of the eye — inflammation of the retina and choroid.

People who wear contact lenses may have a higher risk of infection with acanthamoebic keratitis and the incidence of this infection in hard lenses is 9.5 times that of soft. The incidence of the infection is increasing because of the growing use of hard lenses for orthokeratology.

2.6.2 Trachoma

Trachoma is one of the leading causes of preventable blindness in the world. It is linked to extreme poverty and poor sanitation and is therefore almost entirely a disease of undeveloped countries. The disease is caused by the bacterium *Chlamydia trachomatis*, and leads to repeated conjunctivitis and a mucous discharge. The eyes are also irritated and the cornea can be damaged by:

- a reduction in the amount of tears produced
- difficulty in closing close the eyelids (which lubricate the eye and help flush away dust and dirt)
- the triggering of trichiasis, where the eyelid and eyelashes turn in on the eye.

The conjunctivitis clears up after a month or so, but the disease is easily spread, particularly in places where there is little water for people to wash their hands and faces regularly. The discharge from infected eyes attracts flies that then land on other people's skin. People in crowded households or neighbourhoods are particularly vulnerable.

Although the disease is linked to developing countries, where living conditions are crowded and hygiene is poor, it is also found in some remote Aboriginal communities in eastern Australia and the Northern Territory.

2.7 Possible risk factors for eye disease

A number of factors have been postulated to cause eye disease. The most common factors are smoking, alcohol, diet and ageing:

- Smoking is thought to affect eye health through oxidative stress. Antioxidants help maintain lens transparency, so smoking may interfere with the protection from antioxidative nutrients (Kelly et al 2005). Oxidative stress in the RPE may contribute to macular degeneration (Bailey et al 2004).
- Alcohol is a difficult risk factor to isolate because it is often associated with smoking and can inhibit the absorption of nutrients. Alcohol may work directly on the proteins in the lens itself and indirectly by affecting absorption of nutrients important to the lens (Hiratsuka et al 2001).
- Good nutrition is thought to promote eye health, but it is unclear whether there are associations between eye diseases and certain dietary factors such as:
 - fatty acids — found in the retina, these are essential for eye development and may protect against the growth of abnormal blood vessels; changes in the composition of fatty acids in the membrane of the lens may cause cataracts
 - lutein and zeaxanthin, and caretenoids — these are found in the lens and the pigment of the retina and also in green leafy vegetables, which have antioxidant properties and which may protect against cataract and macular degeneration
 - nutritional supplements (eg riboflavin, thiamin, vitamin C, vitamin E, vitamin A, zinc); for example, vitamin A is required in the production of rhodopsin, the visual pigment used to see in low light levels.
- As discussed above, many structures in the eye change as we age, and this can result in eye disorders and diseases.
- Near work such as reading, watching TV or looking at a computer screen has been associated with the development of myopia.
- Both visible and ultraviolet light may damage the eye. In particular, the cornea is a good absorber of ultraviolet (UV) light and if it is damaged this can lead to cataracts.

In addition to diabetic retinopathy (discussed above), diabetes is also thought to be a risk factor for other eye diseases such as cataract (AIHW 2005). The eye may be adversely affected by problems with blood sugar levels, microvascular damage and associated conditions such as poor nutrition and obesity.