Keywords Special sense organs/ Presbyopia/Presbycusis/Tinnitus

This article has been double-blind peer reviewed

In this article...

- Age-related changes to two special sense organs
- Physiological processes behind declining sight, hearing and balance
- Common sight and hearing pathologies arising in older age

Anatomy and physiology of ageing 6: the eyes and ears

Key points

1. **Of all age-related changes to the special sense organs, the most dramatic are seen in the eyes and ears**
2. **Presbyopia is the age-related decrease in the ability to see objects that are near**
3. **Presbycusis is the sum of all conditions that lead to decreased hearing with age**
4. **Changes to the vestibular system of the inner ear contribute to balance problems in older people**
5. **Regular testing allows early diagnosis of common age-related sight and hearing problems**

Authors John Knight is senior lecturer in biomedical science; Chris Wigham is senior lecturer in interprofessional studies; Yamni Nigam is associate professor in biomedical science; all at the College of Human Health and Sciences, Swansea University.

Abstract The special senses – sight, hearing, smell, touch and balance – allow us to perceive the world and communicate. Like all body systems, they undergo age-related changes that negatively affect their function. Physiological changes to the eyes and ears mean older people gradually see, hear and balance less well. The changes also increase the risk of conditions such as cataracts, age-related macular degeneration, and conductive and sensory hearing loss. This sixth article in our series on the effects of age on the body describes what happens to the eyes and ears.

Citation Knight J et al (2017) Anatomy and physiology of ageing 6: the eyes and ears. *Nursing Times* [online]; 113: 7, 39-42.

The special sense organs – the eyes, ears, nose, tongue – detect information coming from the environment, such as light, sound, smells and tastes, which is then relayed to the brain where it is processed into meaningful sensations. Diminished acuity of the special senses reduces our ability to perceive the world and communicate. All the senses go through an age-related decline, but the most dramatic changes are seen in the eyes and ears. This sixth article in this series on the effects of ageing on the different body systems examines the age-related changes in the eyes and ears.

The ageing eye

Vision is affected by the ageing of the internal and external structures of the eye. Its decline is gradual and linear, and detectable changes begin in the third decade of life. The main changes are outlined in Fig 1.

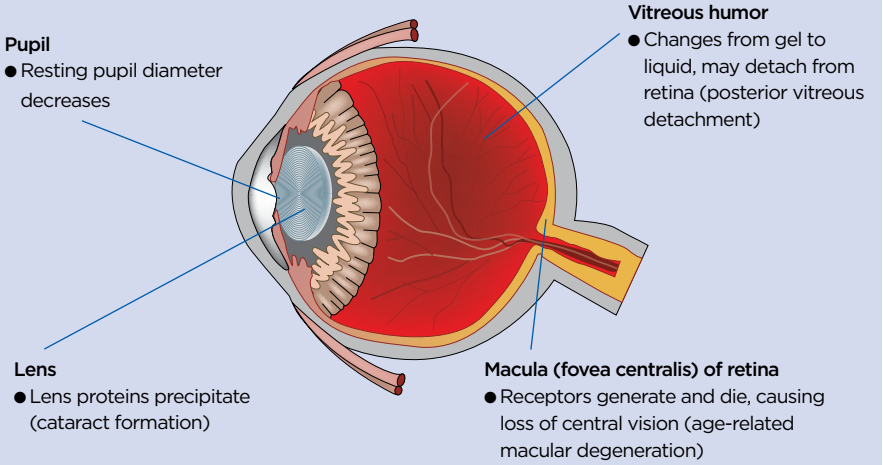
Anatomical changes

The retro-orbital fat, which protects and cushions the eye, atrophies with age, causing the eyeball to recede into its socket (enophthalmos). As a result, eyelid tissues become lax and the levator muscles in the eyelids weaken, causing the eyelids to droop (ptosis). Drooping eyelids can gradually obstruct the upper field of vision.

Sinking eyeballs and drooping eyelids often lead to the conjunctiva lining the eyelids (tarsal conjunctiva) failing to sufficiently lubricate the front of eye (cornea). This can result in an air space developing between the lid and the cornea, particularly at night, potentially leading to epithelial breakdown (Sobel and Tienor, 2013; Liang et al, 2011).

In some people, the weakening of the muscles supporting the eyelids and loosening of the eyelids result in the eyelashes turning inwards (entropion) and irritating the cornea's surface, which could lead to ulceration. A significant weakening of the muscles supporting the lower eyelids can result in them 'flopping away' from the eyeball (ectropion), which can then dry out and become irritated. Symptoms of entropion and ectropion can be relieved by anti-inflammatory eye drops or artificial tears,

Fig 1. **Age-related changes to the eye**



while surgery to tighten the skin and muscles of the eyelid can provide permanent relief (Garrity, 2016).

Changes affecting tears

With age, the lacrimal glands produce fewer tears, while the composition of tears changes, and the wetting efficiency and stability of the tear film is reduced. This leads to dry eye syndrome in up to 14% of the over-65s. Irritation, grittiness and pain can ensue and affect many activities, such as reading or watching television. Persistent irritation can make the cornea less sensitive, which in turn can diminish the ability to detect injury or infection. Many people find the use of artificial tears effective (Bit.ly/NHSChoices-DryEyeTreatment; Dry Eye WorkShop, 2007).

Vision changes

Presbyopia

Throughout life, equatorial lens cells divide and new cell layers are added to the outside of the lens. Since the lens cannot grow in size (if it did it would soon outgrow the eyeball), its cells must be compressed, which results in the lens becoming increasingly dense and inflexible. The lens, therefore, becomes progressively less able to change shape to be able to focus light on the retina.

Presbyopia is the age-related reduction in the ability to see near objects. It typically presents as an inability to read text positioned close to the eye and generally develops in the 40s and 50s. Presbyopia results from a reduction in the ability of the intraocular lens to change shape. The distance from the eye at which print can be read (near point) increases from about 10cm at the age of 20 to over 100cm by the age of 70. Most people manage presbyopia by using correcting reading glasses (Boyd, 2016).

Late-stage ageing of the lens and cataracts

New lens cells continue to be produced throughout life, so the lens continues to increase in density. This can cause particular light frequencies to be absorbed and the lens to take on a yellowish hue, affecting contrast sensitivity and the accurate perception of colours.

When the concentration of proteins in the lens becomes very high, precipitation occurs. This is seen as a cataract. The scattering of the light causes a glare or a halo effect when looking at bright lights. As the densest area of the lens is the centre, this is where age-related cataracts are most commonly seen.

Cataracts can make it difficult to see in certain circumstances – for example, when driving at night. They can also interfere with the ability of certain wavelengths of light to enter the eye, thereby reducing colour perception: people with cataracts may wear garish clothing due to their compromised colour vision.

Individuals with poorly controlled diabetes are at much greater risk of developing cataracts because increased blood glucose encourages the build-up of damaging levels of sorbitol in the lens (Knight et al, 2017).

Cataracts are managed by removing the lens's contents from the capsular bag and placing a small intraocular lens inside the capsule to provide refractive power. The power of the intraocular lens can be chosen to suit the patient's wishes and lifestyle (Truscott, 2003).

Pupil changes and poor night vision

One role of the pupils is to regulate the amount of light entering the eye. With age, their diameter decreases, reducing the admittance of light. Age also has a negative effect on the pupils' ability to adapt to changes in light intensity – for example, when going from light to dark. Adapting to the dark requires the photosensitive cells of the retina to regenerate the photopigment rhodopsin; this is considerably delayed with age, which contributes to night-vision problems.

These changes increase older people's risk of falls and other accidents, for example, when leaving a brightly lit bathroom to walk up or down a flight of poorly lit stairs (Rukmini et al, 2017; Turner and Mainster, 2008; Bitsios et al, 1996).

Posterior vitreous detachment

The eye consists of two hollow chambers separated by the lens. The anterior chamber is filled with a watery fluid (aqueous humor) and the posterior chamber with a jelly-like material (vitreous humor). The composition of the vitreous humor can change from a gel to liquid with age and, in some people, it shrinks, collapses and separates from the retina. This posterior vitreous detachment often manifests as discrete opacities (floaters) or sheering patterns in the field of vision (Bishop et al, 2004).

Age-related macular degeneration

With age, cone photoreceptor cells in the fovea, which provide high-quality colour vision, begin to die, eventually resulting in age-related macular degeneration (ARMD). This is thought to be caused by changes to the cells of the retinal pigment epithelium (RPE), which lies next to, and maintains, the photoreceptor cells.

There are two types of ARMD: dry (90% of cases) and wet (10%). Dry or atrophic ARMD is characterised by a gradual bilateral loss of vision as the RPE degenerates. Wet or exudative ARMD is caused by the growth of new blood vessels in the space between photoreceptors and RPE (subretinal space) and the leakage of serous fluid from these new vessels. Wet AMRD has a more rapid onset and causes more severe loss of vision.

In ARMD, pale yellow-white elevated spots called drusen appear on the retinal surface, distorting vision and reducing visual acuity. Their appearance steadily increases after the age of 60 years. ARMD accounts for half of all visual impairments among people aged 75 and over (Bit.ly/AMDMacularDegeneration; Bit.ly/NERC-MacularDegeneration; Forester et al, 2001).

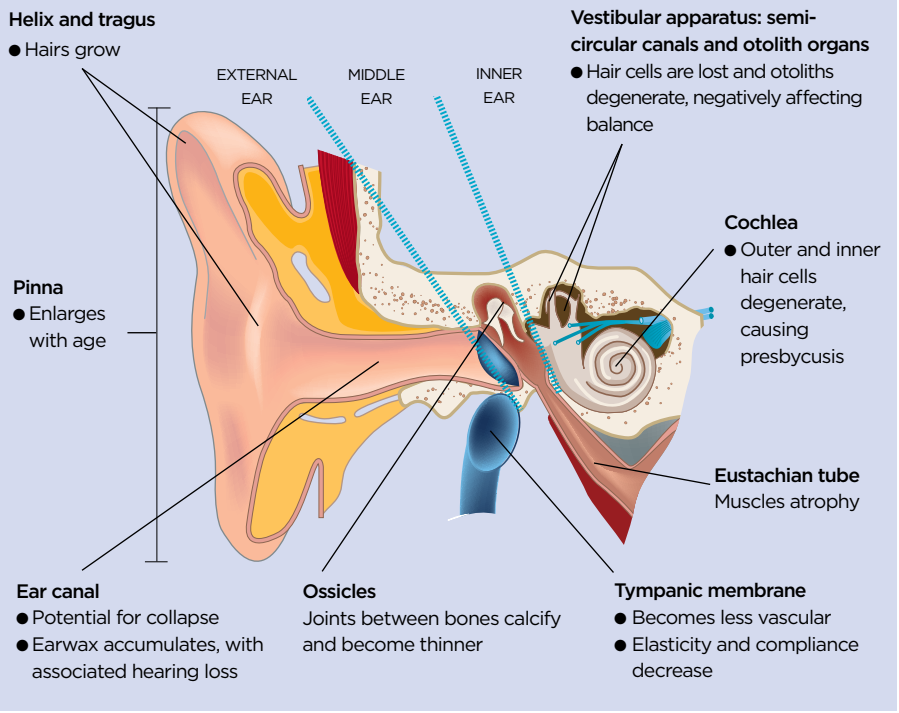
The ageing ear

The ear is the organ of hearing but also plays the major role in our sense of balance.

CATHERINE HOLLICK

Problems with hearing are the most common sensory disorder associated with ageing. At age 61-70 years, around a third of people develop problems understanding speech if there is ambient background noise, and in those aged 85 years and over this rises to around 80% (Sogebi, 2015). Age-related changes to the ear are shown in Fig 2.

Fig 2. **Age-related changes to the ear**



Outer ear changes

The auricle (pinna) collects sound waves and directs them through the ear canal (auditory meatus) to the eardrum. With age, the pinna often becomes larger and features more external hair on the tragus and lower helix; these changes are more often seen in men. The pinna becomes increasingly dry and scaly in both sexes.

The auditory meatus produces earwax (cerumen), which moistens the ear canal and is mildly antiseptic, helping to keep the ear free from infection. Unless compressed and pushed inwards by implements such as cotton buds, cerumen gradually works its way out (the ears are often described as self-cleaning).

With age, the ceruminous glands become less active and produce less earwax, which can lead to the auditory meatus becoming increasingly dry and prone to infection. The cartilaginous components that form the walls of the auditory meatus can lose elasticity, degrade and sometimes collapse, which increases the likelihood of ear canal collapse (Howarth and Shone, 2006). A drier environment and ear canal collapse both increase the likelihood of cerumen accumulation and obstruction, commonly resulting in conductive hearing loss. Older people may need to use earwax softeners before having excess wax removed by micro-suction at audiology clinics or by syringing at GP surgeries.

Middle ear changes

The middle ear consists of the ear drum (tympanic membrane) and a hollow, air-filled chamber spanned by three tiny bones (auditory ossicles):

- Hammer (malleus);
- Anvil (incus);
- Stirrup (stapes).

The tympanic membrane vibrates in harmony with the sound waves collected by the outer ear, and these vibrations are transmitted and amplified across the middle ear by the three auditory ossicles. With age, the tympanic membrane becomes less vascular and begins to thin and stiffen (Liu and Chen, 2000; Weinstein, 2000). In older people, the tiny synovial joints between the three auditory ossicles are often stiff and calcified, leading to less efficient conduction and amplification of sound waves.

The air-filled chamber of the middle ear is connected to the back of the pharynx by the auditory or Eustachian tube: this ensures the pressure is kept relatively equal on both sides of the eardrum to prevent pressure building up and damaging the tympanic membrane. The musculature lining the auditory tube often undergoes age-related atrophy, which may interfere with the tube's opening during swallowing, thereby increasing the risk of pressure differences between the two sides of the eardrum.

Inner ear changes

The inner ear consists primarily of the:

- Cochlear – which detects sounds;
- Vestibule and semicircular canals – which are responsible for balance.

The cochlear is a fluid-filled, spiral-shaped organ that receives sound waves directly from the stirrup. Sound waves travel rapidly through the fluid of the cochlear and are detected by special sensory receptor cells called hair cells. These relay auditory signals to the cochlear nerve, which delivers them to the auditory cortex of the brain, where they are perceived as sound. Our sense of hearing is most acute at the age of 10 years and gradually declines thereafter.

Presbycusis

Almost everyone experiences a deterioration in hearing as they age, and currently there is no way of preventing or reversing these age-related changes. Presbycusis is "the sum of all conditions that lead to decreased hearing sensitivity with age"; it can be accelerated by exposure to loud noise, conditions that impair cardiovascular function and nerve damage (Parham et al, 2011). Presbycusis is usually associated with a progressive degeneration of the hair cells and neurones in the cochlea.

It has been suggested that a lifetime exposure to loud noises cumulatively damages hearing. Indeed, some people living in isolated, non-industrial communities in Africa and India have little age-related hearing loss. Inheritance of certain genes, increased exposure to free radicals and toxins, and decreasing blood supply to the inner ear (Danner and Harris, 2003) contribute to presbycusis and the rate at which it develops. A slowing in the brain's processing of auditory information is another contributing factor.

Presbycusis is particularly associated with a declining ability to hear high frequencies, which are important for interpreting speech. As a result, older people find it increasingly difficult to follow and join in conversations, especially when competing background sounds (for example, from television or music) are

CATHERINE HOLLICK

present. This can restrict interactions and contribute to loneliness and social isolation (Parham et al, 2011).

Tinnitus

Tinnitus is the hearing of a noise – often a ringing, buzzing, humming or whooshing – in the absence of any external sound; it is occasionally reported as having a musical quality (Bit.ly/AllAboutTinnitus). The condition has a variety of causes, including:

- Changes in blood flow in the ear;
- Drug toxicity (from example, adverse reactions to gentamicin);
- Muscular spasms in the ear;
- Loss of hair cells.

However, the major cause of tinnitus might be the lack of sensory input reaching the auditory cortex of the brain. Tinnitus has been compared to phantom sensations perceived in a non-existent limb after amputation: in some people, the sounds associated with tinnitus persist even after the cochlear nerve has been severed (Danner and Harris, 2003). As ageing is associated with a loss of sensory hair cells, the resultant reduction in sensory input to the brain may explain why prebycusis and tinnitus often coexist.

There is mounting evidence that exposure to loud sounds throughout life can both accelerate age-related hearing loss and increase the risk of tinnitus. It is a concern to audiologists that growing numbers of young people attend loud concerts and listen to loud music through headphones for long periods – this is likely to accelerate their hearing loss and lead to hearing problems and deafness much earlier in life (Kujawa and Liberman, 2006).

Diminished sense of balance

The ability to balance the body at rest (static balance) and when moving (dynamic balance) relies on a complex interplay between different sensory systems including sight, touch and the vestibular system of the inner ear. To trigger the intricate motor coordination of skeletal muscles required to maintain balance, various regions of the brain need to quickly process a large and continuous input from these sensory systems (Horak, 2006).

The vestibular system of the inner ear consists of a labyrinth containing semicircular canals and their hair cells, and the otolith organs (utricle and saccule). All are key in maintaining balance. With age, the vestibular apparatus progressively loses hair cells – some people aged 70 years or over experience up to 40% reduction in hair cells in the semi-circular canals (Rauch et al, 2001).

Other notable changes are the progressive fragmentation and degeneration of the otoliths (tiny stones made of calcium carbonate), particularly in the saccule. The number of vestibular nerve cells also diminishes from around the age of 60 years. These changes mean that, with age, our sense of balance becomes impaired and we may experience dizziness. Poor balance and dizziness, together with frailty and reduced reaction times, contribute to the risk of falls – a major concern in older people. Each year an estimated 20-40% of those aged 65 and over fall at home (Shupert and Horak, 2017).

Regular testing

While little can be done to avoid the effects of ageing on sight and hearing, it is vital to encourage older people to have regular eye and hearing tests (Box 1). This means appropriate glasses and/or hearing aids can be dispensed, and common age-related pathologies such as cataracts, ARMD, and conductive and sensory hearing loss can be diagnosed early. Many people now have their eyes and hearing tested by high-street optometrists in addition to relying on GP referrals.

People who have diabetes and hypertension need tests more often because both conditions can adversely affect sight and hearing. People with a family history of glaucoma should also be encouraged to undergo regular testing because this condition (which is not part of the normal ageing process) can be hereditary. **NT**

Box 1. **Eye and hearing tests: recommended frequency**

- **From the age of 70 years onwards:** eye test at least every two years
- **From the age of 60 years onwards:** hearing test every 2-3 years
- **People with a family history of glaucoma:** eye test every month until intraocular pressure is normalised and then every year

Anatomy and physiology of ageing – updated series

Article	Date
Part 1: the cardiovascular system	Feb
Part 2: the respiratory system	Mar
Part 3: the digestive system	Apr
Part 4: the renal system	May
Part 5: the nervous system	Jun
Part 6: the eyes and ears	Jul
Part 7: the endocrine system	Aug
Part 8: the reproductive system	Sep
Part 9: the immune system	Oct
Part 10: the musculoskeletal system	Nov
Part 11: the skin	Dec

References

Bishop PN et al (2004) Age-related changes on the surface of vitreous collagen fibrils. *Investigative Ophthalmology and Visual Science;* 45: 4, 1041-1046.
Bitsios P et al (1996) Changes in autonomic function with age: a study of pupillary kinetics in healthy young and old people. *Age and Ageing;* 25: 6, 432-438.
Boyd K (2016) *What is Presbyopia?* American Academy of Ophthalmology. Bit.ly/AAOPresbyopia
Danner CJ, Harris JP (2003) Hearing loss and the aging ear. *Geriatrics and Aging;* 6: 5, 40-43.
Dry Eye WorkShop (2007) The definition and classification of dry eye disease: report of the Definition and Classification Subcommittee of the International Dry Eye WorkShop. *Ocular Surface;* 5: 2, 75-92.
Forrester JV et al (2001) *The Eye: Basic Sciences in Practice.* New York, NY: Elsevier.
Garrity J (2016) *Entropion and Ectropion.* Bit.ly/MerckEntropionEctropion
Horak FB (2006) Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and Ageing;* 35: Suppl 2, ii7–ii11.
Howarth A, Shone GR (2006) Ageing and the auditory system. *Postgraduate Medical Journal;* 82: 965, 166-171.
Knight J et al (2017) Diabetes management 2: long-term complications due to poor control. *Nursing Times;* 113: 4, 45-48.
Kujawa SG, Liberman MC (2006) Acceleration of age-related hearing loss by early noise exposure: evidence of a misspent youth. *Journal of Neuroscience;* 26: 7, 2115-2123.
Liang L et al (2011) Ocular surface morbidity in eyes with senile sunken upper eyelids. *Ophthalmology;* 118: 12, 2487-2492.
Liu TC, Chen YS (2000) Aging and external ear resonance. *International Journal of Audiology;* 39: 5, 235-237.
Parham K et al (2011) Challenges and opportunities in presbycusis. *Otolaryngology – Head and Neck Surgery;* 144: 4, 491-495.
Rauch SD et al (2001) Decreasing hair cell counts in aging humans. *Annals of the New York Academy of Sciences;* 942: 220-227.
Rukmini AV et al (2017) Pupillary responses to short-wavelength light are preserved in aging. *Scientific Reports;* 7: 43832.
Shupert C, Horak F (2017) *Balance and Aging.* Portland, OR: Vestibular Disorders Association. Bit.ly/ShupertBalance
Sobel RK, Tienor B (2013) The coming age of enophthalmos. *Current Opinion in Ophthalmology;* 24: 5, 500-505.
Sogebi OA (2015) Middle ear impedance studies in elderly patients: implications on age-related hearing loss. *Brazilian Journal of Otorhinolaryngology;* 81: 2, 133-140.
Truscott RJW (2003) Human cataract: the mechanisms responsible; light and butterfly eyes. *International Journal of Biochemistry and Cell Biology;* 35: 11, 1500-1504.
Turner PL, Mainster MA (2008) Circadian photoreception: ageing and the eye's important role in systemic health. *British Journal of Ophthalmology;* 92: 11, 1439-1444.
Weinstein BE (2000) *Geriatric Audiology.* New York, NY: Thieme.

For more on this topic go online...

- A communication protocol to help patients with sensory impairment **Bit.ly/NTSensoryImpairment**