The Senses

The Special Senses

The Senses

All human awareness and knowledge are dependent on the detection, and interpretation, of both external and internal stimuli.

By tradition, the human body is attributed with five senses: sight, smell, taste, hearing, and touch, but a full list must include senses for:
balance, movement, hunger, thirst, plus the autonomic sensing of blood pressure and blood gases.

Sensory Receptors

The dendrites of distal sensory nerve neurones form *sensory receptors*. In some cases, the receptors are directly stimulated, in other cases the stimuli are generated in other specialised organs or tissues.

Classes of Sensory Receptor

Sensory receptors may be classified according to their location and to their function:

Exteroceptors. These are located throughout the peripheral areas of the body. They respond to touch, pressure, pain (harmful stimuli), and temperature.

Interoceptors. These are located within the body. They respond to stimuli such as blood gas concentrations, and smooth muscle stretching.

Proprioceptors. These are situated in areas such as joints, and the ear. They sense the positions of the joints, and of the body in space.

Teleceptors. These are located in the eyes, ears, and nose. They respond specifically to provide the senses of sight, hearing, and smell.

Chemoreceptors. These respond to chemical stimuli, or changes in chemical concentration.

Mechanoreceptors. These respond to physical pressure, force and movement. They are the most widespread sensors found throughout the body.

Nociceptors. These repond to stimuli which could signal harm to the body.

Photoreceptors. These are only found in the eyes and respond to light.

Thermoreceptors. These respond to temperature change.

General Senses

The *general senses* are those which are distributed over the skin surface, and to a certain extent, within specific organs.

Touch

Touch sensation is divided into *light touch* - detected by receptors close to the surface of the skin, and *pressure* - detected by slightly deeper receptors as a deformation of the skin.

Heat and Cold

Heat and cold are detected by different receptors, termed *warm spots* and *cold spots*, found throughout the surface of the body.

Pain

Pain is an unpleasant sensation caused when *nociceptors* detect harmful stimuli or tissue damage. Nociceptors are present throughout the body except in brain tissue and in the intestines.

The nature of the pain caused is determined by the location and nature of the harmful stimulus.

Referred pain

Pain originating in an internal organ is often perceived as being on the body surface or at some other location - away from the actual cause.

It is believed that this *referred pain* occurs because the neurone paths for both areas combine into a common path, and the brain is unable to differentiate the source of the pain.

The Special Senses

The special senses of sight, hearing, taste, and smell are provided by dedicated organs and sensory nerve pathways.

Sight

Sight is considered to be the most sensitive sense in the human body.

Eyes

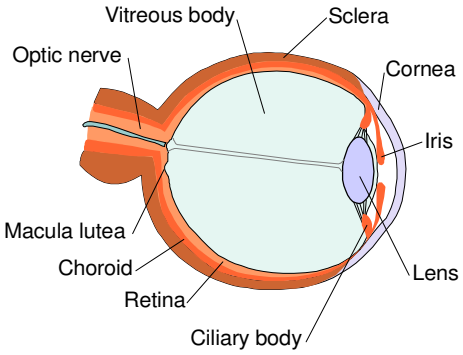
The organs of sight are the *eyes*, situated within the orbital cavities of the skull. [*Figure 8 - 1*]

The eyes stimulate the optic nerves, the resulting impulses then being interpreted by the brain into perceived images.

The existence of two eyes, separated by a short distance, allows the perception of distance, and of three dimensional objects, by the brain's interpretation of two very slightly different images.

Figure 8 - 1 an eye

A sagittal section through an eye



The outside of the eye is made up from three layers of tissue: sclera, choroid, and retina.

Sclera (outer layer)

The *sclera* is a firm fibrous membrane which encloses the eye, maintains its shape, and provides an attachment for the muscles which move the eye.

Anteriorly, the sclera becomes the *cornea*, a colourless transparent membrane which allows light into the eye.

Choroid (middle layer)

The *choroid* lines the posterior 70% of the eye. It contains many blood vessels and is deeply pigmented so that it absorbs light.

Anteriorly, the choroid links to the iris, and to the *ciliary body*, consisting of smooth muscle formed into *ciliary muscles* which control the lens.

The *lens* is an elastic solid body enclosed in a transparent capsule. The lens focuses light onto the retina. The curvature, and thus the focal length of the lens may be altered by the ciliary muscles.

The *iris* is a ring of pigmented cells and muscle fibres. When the muscles contract, the iris constricts, reducing the central aperture, or *pupil*.

The iris controls the amount of light reaching the retina by opening in dim light, and closing in bright light.

Retina (inner layer)

The *retina* lines the interior of the eye, except for the section from the ciliary body forwards.

The retina is composed mainly of nerve and fibre cells, with light sensitive cells on the inner face.

These cells are divided into *rods* which sense black to white shades, and *cones* which sense colour.

The eye contains approximately 125 million rods and 7 million cones.

The central area of the retina, known as the *macula lutea*, contains only cones. The remainder of the retina contains a mixture of rods and cones.

The optic nerve connects to the eye at a point on the nasal side of the posterior centre. This point has no rods or cones, and is known as the *blind spot*.

Interior of the eye

The main body of the eye is filled with a clear gel called *vitreous humour*.

The anterior part of the eye is filled with a clear fluid called *aqueous humour*.

Vision

Vision occurs when light waves are focused onto the retina, and cause nerve impulses which the brain can interpret into an image.

Focusing

The ciliary muscles adjust the lens - contraction causes the lens to thicken which reduces its focal length and allows focusing of light from near objects onto the retina. Relaxation conversely allows focusing of the light from distant objects.

Perception of light

Rods contain the pigment *rhodopsin*. This is bleached when it absorbs light energy. The extent of the bleaching depends on the amount of light energy absorbed.

This, in turn, causes nervous stimulation through a complex photo-chemical reaction.

Rods with bleached rhodopsin do not respond further to light, but the rhodopsin recovers after a short period of time. (This delay is noticeable when moving from an area of light into a dark area).

There are three varieties of cones, which contain different light sensitive pigments. These respond separately to the wavelengths of light which correspond to the colours of red, blue, and green.

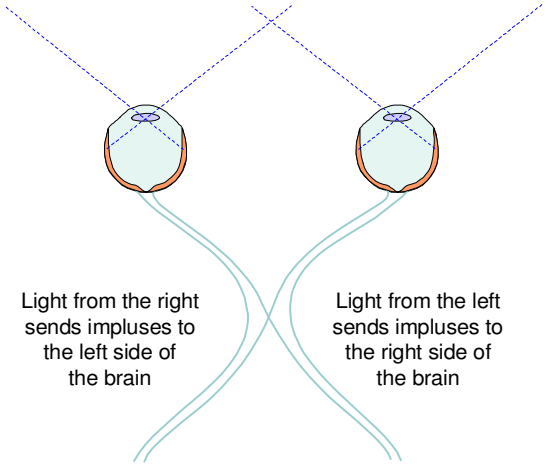
Rods are 50 - 100 times more sensitive than cones, hence 'night vision' is seen only as shades of grey, and in low light levels the best vision is obtained by focusing outside the macula lutea - by not looking directly at an object.

Optic chiasma

The layout of the optic nerves is such that the nerve fibres from the nasal side of each eye cross over, whereas those from the lateral sides do not. This crossover is known as the *optic chiasma*, [*Figure 8 - 2*] and means that light from the right side, into both eyes, causes nervous stimulation to the left side of the brain, and vice versa.

Figure 8 - 2 the optic chiasma

The basic arrangement of the optic chiasma



Movement of the eyes

Each eye is moved by a set of six muscles, composed of striated muscle tissue, under the control of the conscious will.

Accessory Organs

The eyes are delicate organs and are protected by additional external structures:

Eyebrows. These are formed by arched ridges of the frontal bone. Growths of hairs prevent sweat and other contaminants being passed into the eyes.

Eyelids. These are pairs of moveable folds of tissue, above and below the eyes.

The eyelids are lined with fine transparent membranes called *conjunctiva*, which also cover the fronts of the eyes.

The front margins of the eyelids are lined with hairs, or *eyelashes*, which help to protect the eyes.

Lacrimal glands. These secrete tears which reach the eye through a series of ducts.

Tears are watery fluid which mixes with secretions from other glands in the eyelids to lubricate, and wash, the conjunctiva.

After bathing the eyes tears normally drain via *naso-lacrimal ducts*, leading from the medial edge of each eye socket, into the nasal cavity.

Smell

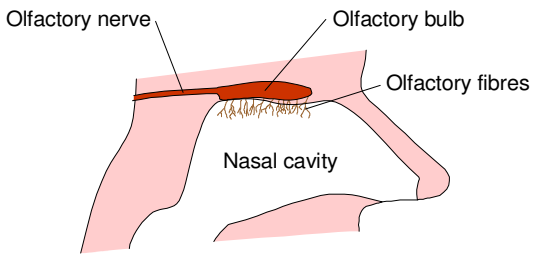
The sense of *smell*, also known as *olfaction*, operates through detecting minute quantities of specific chemical compounds in the nasal cavity.

Olfactory Nerves

The *olfactory nerves* are the nerves of smell. [*Figure 8 - 3*] They originate as fibres in the roof of the nasal cavity.

Figure 8 - 3 olfactory nerves

A partial sagittal section through the nasal cavity showing the arrangement of the olfactory nerve sensors



The fibres are sensitive to chemical stimulation by inhaled vapours, and soluble particles. The resulting stimuli are combined in the *olfactory bulb* before being passed into the olfactory nerve, and the brain, where they are interpreted to produce the sensation of smell.

The sense of smell is such that continual exposure to any one particular odour results in a reduced perception of that odour.

Hearing

The *ears* [*Figure 8 - 4*] provide the mechanisms for the sense of *hearing*. They also provide the senses of balance and position.

The ear is divided into three sections: the external ear, the middle ear, and the inner ear.

External Ear

The *external ear* comprises two parts:

Auricle. (or *pinna*) This is the visible portion projecting from the head. It is formed mainly from fibro-elastic cartilage covered with skin.

External acoustic meatus. This is a tube which channels sound waves from the auricle to the tympanic membrane.

Oil glands and modified sweat glands in the external acoustic meatus secrete *cerumen*, or ear-wax. This, together with fine hairs on the inside of the meatus, provides protection against the entry of small insects and foreign matter.

Middle Ear

The *middle ear* is a small chamber between the tympanic membrane and the inner ear.

The *tympanic membrane*, or *eardrum*, separates the inner ear from the external ear. It is a thin layer of fibrous tissue containing nerve fibres and small blood vessels.

The *auditory ossicles*, a set of three small bones (*malleus*, *incus*, and *stapes*) form a lever network. The malleus is attached to the tympanic membrane, and as this vibrates in response to sound waves, the vibrations are passed through the incus and stapes to the inner ear.

The ossicles are held in place by ligaments and by two minute muscles which alter the perceived loudness of sound by pulling on the ossicles.

The middle ear is connected to the nasal pharynx via the *auditory tube*, or *Eustachian tube*. This allows equalisation of pressure on both sides of the tympanic membrane. The tube is normally closed, but opens during swallowing, yawning, or 'blowing the nose'.

Inner Ear

The *inner ear* contains the actual organs of hearing. It also contains the organs of balance.

The inner ear consists of two main structures: the bony labyrinth and the membranous labyrinth.

The *bony labyrinth* is a series of channels within the temporal bone.

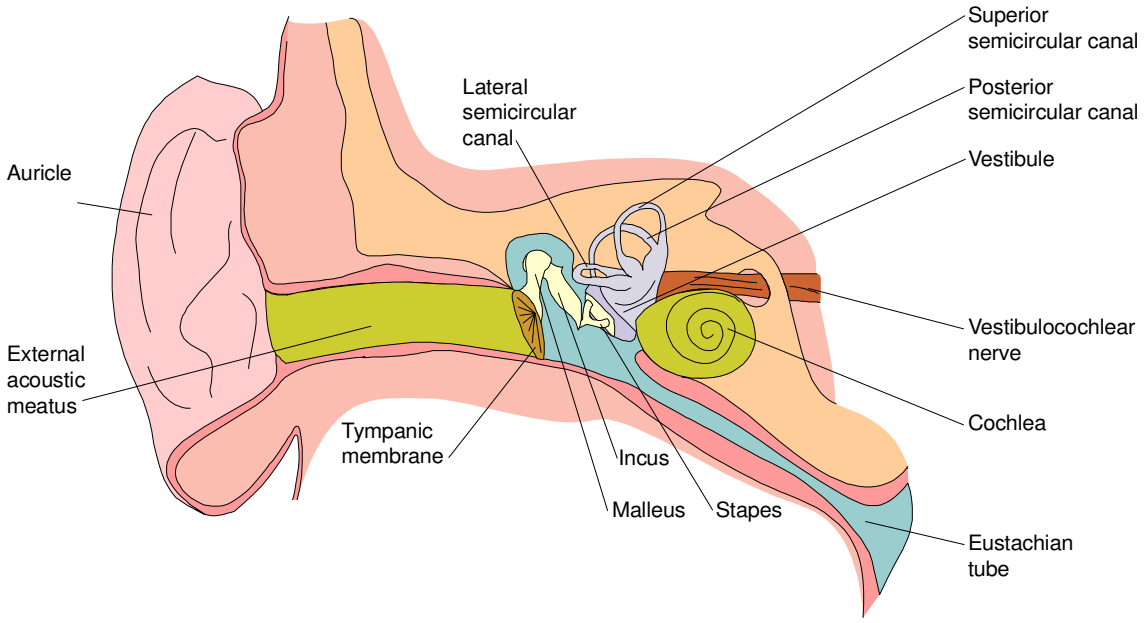
The *membranous labyrinth* fits inside the body labyrinth, with the same basic sections, and following the same layout.

The watery fluid *perilymph* surrounds the membranous labyrinth, separating it from the body labyrinth.

The membranous labyrinth contains the fluid *endolymph*.

Figure 8 - 4 an ear

A frontal section through an ear



The labyrinths are formed in five sections:

Vestibule. This is the section nearest the middle ear. Sound waves enter the vestibule from the stapes bone, via an orifice known as the *oval window*.

Cochlea. This resembles a snail's shell, being a concentric spiral. Its origin is continuous with the vestibule.

The cochlea within the membranous labyrinth contains the *spiral organ* (*organ of Corti*). This holds the nerve endings of the cochlear nerve which provide the sense of hearing.

Semicircular canals. (3) These are tubes, arranged such that there is one in each of the three planes of space. They are continuous with the vestibule.

They contain the sensory nerve endings for balance.

Perception of Sound

Sound occurs when pressure waves of air are created by mechanical vibration in the frequency range of approximately 10Hz to 18kHz.

These waves enter the ear and cause the tympanic membrane to vibrate. These vibrations are conducted from the tympanic membrane into the auditory ossicles, and are passed on by the stapes into the vestibule.

The resulting minute pressure waves then pass into the cochlea, where they stimulate the organ of Corti, and lead to auditory nerve impulses in the cochlear nerve.

Finally, the nerve impulses pass into the vestibulocochlear nerve and on to the auditory area of the brain, where they are perceived as sound.

Balance

The three semicircular canals are not involved in hearing; they provide the sense of balance.

One semicircular canal (in each ear) is set in each spatial plane. Any change in the position of the head causes minute pressure changes in the perilymph and endolymph. These changes are detected by nerve endings in the vestibule, and are conducted via the vestibular nerve and then vestibulocochlear nerve to the brain.

Taste

Taste, also known as *gustation*, is mainly associated with chemical sensing via the tongue, although the soft palate, the pharynx, and the epiglottis are also capable of detecting taste.

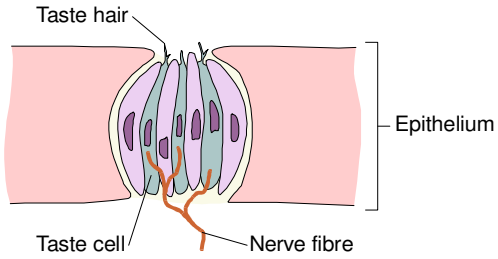
In addition, a large contribution to the perception of taste is provided through the sense of smell.

Taste Buds

Taste buds [*Figure 8 - 5*] are small bundles of cells, and endings of the glossopharyngeal, facial, and vagus nerves. They are distributed within the epithelial surface of taste sensitive organs, and are stimulated by dissolved chemical substances.

Figure 8 - 5 a taste bud

A section through a taste bud



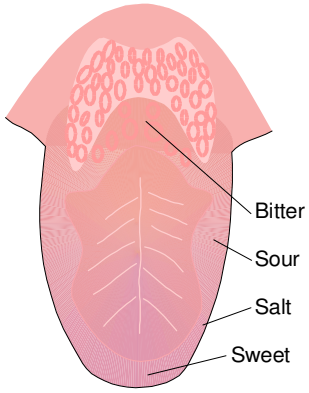
Taste Sensations

The sense of taste is split into just four distinct sensations: sweet, sour, salt, and bitter.

Sweet is sensed mostly on the tip of the tongue, with salt at the sides of the tip, sour at the sides of the tongue, and bitter at the posterior of the tongue. [*Figure 8 - 6*]

Figure 8 - 6 taste sensors

The tongue, showing the layout of taste sensors



The central area of the tongue is largely insensitive to taste sensations.

Ear and Hearing Problems

Benign paroxysmal positional vertigo

Vertigo is a sensation of movement when no movement is occurring.

Benign paroxysmal positional vertigo is believed to be caused by minute particles of solid debris in the posterior semicircular canal, and takes the form of brief periods of vertigo brought on by sudden head movement.

Earache

There are several possible causes for *earache*.

It is most commonly associated with acute infection and inflammation of the inner ear.

Other causes include chronic infections, localised infections, inflammation of the outer ear, a build-up of wax, or neuralgia.

Tooth decay may also cause pain in the ear.

Hearing loss

Hearing loss, or deafness, may occur for a large number of reasons, including genetic and congenital abnormalities, infection and disease, direct injury to the ear, injury to the surrounding bones, the effects of some poisons, long-term exposure to excessive sound levels, and age-related degeneration.

Conductive loss. This occurs through mechanical means, such as a simple blockage of the external acoustic meatus by wax or other foreign substance, or damage to the tympanic membrane or ear mechanisms.

Nerve loss. This occurs when the auditory nerve is damaged, either by injury or through disease.

Labyrinthitis

Labyrinthitis is an inflammation of the inner ear, and is a common cause of vertigo. It often follows on from infections such as the common cold or influenza.

Labyrinthitis may follow more severe infections such as mumps, and may then lead to permanent damage and hearing loss.

Ménière's disease

Ménière's disease leads to excessive endolymph, and dilation of the labyrinth, which distorts the sensation of balance causing attacks of extreme vertigo, as well as causing deafness.

The condition takes the form of repeated attacks, with remission in between, although tinnitus may occur during these times. Eventually, the organ of Corti is damaged by the attacks and permanent hearing loss results.

Tinnitus

Tinnitus is the sensing of noise - often a 'ringing' sound - when no actual sound is present.

It is believed to occur through misinterpretation of nerve impulses from the ear or from other areas of the auditory nerve pathway.

The underlying cause is often unknown, but many factors, including alcohol, medications, poisons, infection, injury, a build-up of wax or other contaminants may contribute, as may hearing loss allowing otherwise masked noises to be audible.

Eye and Vision Problems

The eyes are highly sensitive to any injury or infection, and to many specific problems which impede their effectiveness. Vision may also be affected by some poisons and medications.

Vision problems sometimes accompany other conditions such as head injuries, diabetes, strokes, or brain tumours.

Cataracts

Cataracts are commonly associated with the ageing process, although there are other possible causes such as diabetes and injury. A *cataract* occurs when the eye's lens loses its clarity, becoming cloudy. This occurs as protein molecules in the lens increase in complexity and size, and cease to be fully transparent.

The condition initially causes poor night vision and a sense of haloes around light objects, but as it progresses, daytime vision is reduced, towards blindness.

Conjunctivitis

Conjunctivitis occurs through an infection, usually viral, and inflammation of the conjunctiva.

The condition usually causes a characteristic redness of the affected eye.

Floaters

Floaters are small particles of matter which drift inside the eye. They cause slight visual disturbances, but are normally benign and temporary. They may, however, be an indication of retinal detachment - a section of the retina splitting or breaking free from the choroid.

Glaucoma

Glaucoma is a condition which results from increased pressure inside the eye. This occurs when the aqueous humour fails to drain properly to balance its production.

The increased pressure compresses the junction between the retina and the optic nerve, reducing its blood supply, and causing individual neurones to die.

The condition first shows as 'blind spots' in the peripheral vision, but if not treated, it will eventually lead to complete blindness.

Macular degeneration

Macular degeneration occurs when the layer of epithelium which forms a filter between the retina and its blood supply breaks down. The retina is then exposed to substances which begin to destroy the macula lutea.

As the condition progresses, central vision is lost, although peripheral fields remain.

Retinitis pigmentosa

Retinitis pigmentosa is a progressive degeneration of the retina. Usually, rods are most affected, reducing night vision and peripheral vision. The condition is largely hereditary, and tends to develop during late childhood, although it rarely causes complete blindness.