BIOLOGY

Communications

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1. Humans, and other animals, are able to detect a range of stimuli from the external environment, some of which are useful for communication

Role of receptors in detecting stimuli

A stimulus is a change in the environment. Examples of stimuli include light, sound, temperature, pressure, pain and certain chemicals.

The role of a receptor is to detect a stimulus. Receptors are specialised cells that convert information from the environment into electrochemical signals for translation in the brain.

Sometimes receptors are distributed all over the body, such as touch receptors in the skin. In other cases, particular receptors are concentrated in an organ, such as the eye, or an endocrine gland such as the adrenal gland.

Response to stimuli

Stimulus → Receptor → Messenger → effector → response
In order that a stimulus may produce a response:

1. A receptor must detect the stimulus.
2. A message must then be passed to a messenger, which may be a nerve or a hormone.
3. The messenger then passes information to an effector which may be a gland or a muscle
4. The effector responds to the information.

Reflex reaction: Does not require the involvement of the brain and is therefore quick. Instead, the message goes to the spinal cord and results in a quick response by an effector, such as a muscle.

Range of senses involved in communication

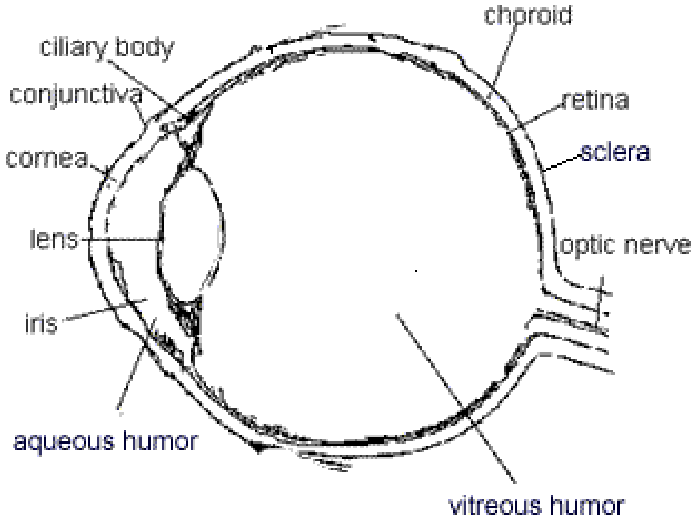
Sense	Examples
Sight (Visual)	• Bio-luminescence in fireflies to attract mates • female chimpanzees have a coloured rump to show when they are ready for mating • Blue-ringed octopus signal an intention to attack by glowing blue rings on their bodies. • Patterns of plumage in birds • Facial expression and posture in humans to signal emotion • Bird courtship display- male peacocks and birds of paradise have highly coloured plumage • Aggressive behaviour in cuttlefish is shown by rapid changes in colour

Smell (Olfactory)	• Animals release pheromones and mark boundary and territory • Male mice will mate immediately they smell a receptive female. • Antelopes scent mark their territory and have scent glands on their faces • Predators such as tigers and lions use smell to locate their prey • Skunks produce a bad smell to keep predators away • Ants produce pheromones to make tracks to lead them back to a nest
Hearing (Auditory)	• Crickets use sound as a warning and to attract mates • Some moths can hear the ultrasonic calls of bats and can avoid being eaten • Frogs use sound for mating calls • Dolphins use echolocation. • Bird song helps females find males of the same species • Humans use speech to communicate complex ideas • Magpies ad kookaburras sing to establish a territory • Humpback whales communicate by sound which can travel hundreds of km.
Touch (Tactile)	• Seagull chicks get their mothers to release food by pecking on their beaks. • Bees dance to communicate the location of food. • Fighting • Defence mechanisms • Friendship and courtship behaviour • Group bonding • Mating • Chimpanzees and primates use grooming as a way of social bonding
Taste	• Some butterflies such as the Monarch butterfly have a bitter taste to communicate that they are poisonous • Bees and blowflies have taste receptors on their feet to help locate food • Catfish have taste receptors on their whiskers
Other Senses	• *electric fields*- bill of a platypus • *magnetic fields* • *polarised light*- bees • *gravity*

Type of receptor	Stimulus	Organ
Mechanoreceptor	• Sound waves • Gravity • Touch • Pressure	• Hair cells in the ear • Skin
Thermoreceptors	• Temperature differences	• Skin
Electromagnetic receptors	Electromagnetic radiation: • Visible light • Ultraviolet • Infra-red • Electric fields	• Skin • Pit organs in snakes • Electric organ in the tail of electric catfish • Electroreceptors in a platypus bill
Chemoreceptors	• Chemicals	• Nose • Tongue

2. Visual communication involves the eye registering changes in the immediate environment

Anatomy and function of the human eye



Light enters through the conjunctiva and then through the cornea through the aqueous humour. Light passes through the pupil and is focused by the lens onto the retina. The iris controls the amount of lights that passes through the pupil. The light is focused through the vitreous humour. The nerve impulse that results from light hitting the retina is sent to the brain through the optic nerve.

Conjunctiva	Continuation of the epidermis of the skin A fine transparent mucous membrane Covers and protects the cornea at the front of the eyeball against friction Keeps it moist
Cornea	Transparent to admit light Refracts light to help form an image on the retina. Performs much of the initial focusing of the image
Sclera	The white of the eye A tough coat of fibres Protects the eyeball against mechanical damage, maintains shape of eyeball
Choroid	A dark pigmented membrane inside the sclera containing pigment and blood vessels Carries oxygen and nutrients to the eye and removes carbon dioxide and wastes. Prevents internal reflection and scattering

Retina	A complex structure of photoreceptors (rods and cones) on the back of the eye. Photoreceptors allow us to see shape, movement and colour, retinal nerve cells convert incoming light into nerve impulses
Iris	A pigmented ring of muscle with a hole in the middle the pupil. It controls the amount of light entering the eye. In dim light the iris relaces and the pupil dilates to let more light in, while in bright light the iris tightens and the pupil contracts.
Lens	A flexible transparent disc Which allows light to enter the rear of the eye Refracts light to allow fine focusing of an image onto the retina onto photoreceptor cells.
Aqueous Humor	A watery fluid between the cornea and the lens Maintains the shape of the eye Refracts light
Vitreous Humor	A jelly-like fluid which fills the area around the retina Maintains the shape of the eye Refracts light
Ciliary Body	Connects choroid with the lens and contains ciliary muscles and suspensory ligament that holds the lens in place Supports the lens and alters the shape of the lens and focuses it
Optic Nerve	Nerve connecting the eye and brain Contains a million nerve fibres that conduct the nerve impulses to the vision centres in the brain

Wavelengths of the electromagnetic spectrum detected by humans and other animals

Humans can detect a small range of the wavelengths of the electromagnetic spectrum – the visible spectrum. 380-750nm (nanometres). The different wavelengths in this band appear as different colours to the human eye.

Ultraviolent (less than 360nm) are detected

Name of animal	Part of electromagnetic spectrum detected	Wavelengths detected
Human	visible	380-750nm
Rattlesnake	infra-red and visible	400-850nm
Deep sea fish	visible	450-500nm
Bee	ultraviolet and visible	300-650nm

PRAC 1 – Eye dissection

1. Observe exterior of eye, the 4 muscle attachments that move eye from side to side and up and down
2. Trim muscle and fat. Note tough white coat, sclera, protecting eye and cornea. Extending back is the white cylinder of the optic nerve
3. Use scalpel to make incision at junction of cornea and sclera. Clear fluid that flows out is aqueous humor
4. Make incision to cut through circumference of sclera. Clear jelly-like liquid is vitreous humor
5. Observe front half of eye- clear biconcave lump of jelly is the lens
6. Lens is surrounded by iris and associated with ciliary body muscles
7. Looking at rear of eye blood vessels embedded in pinkish retina can be seen. Behind coloured layer is black choroid layer preventing internal reflection.

Reasons for the differences in the ranges of electromagnetic radiation detected between different animals

Name of animal	Electromagnetic spectrum used	Reasons
Human	visible	• Active during the day • Uses colour to distinguish food and to gain information about the environment
Rattlesnake	infra-red and visible	• Active at night hunts in dark burrows
Deep sea fish	visible	• Little light penetrates to depth • Uses bioluminescence to communicate • Can only detect blue light
Bee	ultraviolet and visible	• Can detect ultraviolet markings on flowers • uses polarised light for navigation

3. The clarity of the signal transferred can affect interpretation of the intended visual communication

Conditions under which light refraction occurs

Light normally travels in straight lines, but light can bend when it moves from one medium to another medium that has a different density.

Bending of light is called refraction, and occurs at the interface between materials of different densities.

Refractive Media

- Cornea
- Aqueous humour
- Lens
- Vitreous humour

In the eye, refraction occurs when light passes from the air to the cornea, from the cornea to the aqueous humor, from the aqueous humor to the lens and from the lens to the vitreous humor. Light spreading out from one point on an object can therefore be focused on a particular point on the retina.

The cornea, aqueous humor, lens and vitreous humor are all made of substances of differing optical density. Most of the refraction in the eye takes place at the cornea. Here, there is the largest change in the index of refraction, as light leaves air and enters the cornea. Because the ciliary muscles can change the shape of the lens, the amount that the lens refracts varies. This enables focusing on objects at differing distances.

Accommodation

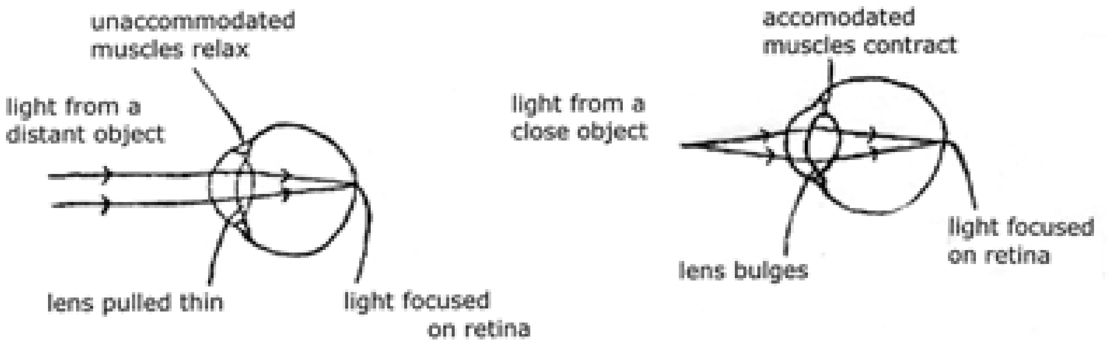
Accommodation is the process by which the lens changes shape to focus images from objects at different distances onto the retina. The image needs to fall on the fovea, which has the greatest density of cones to ensure visual acuity. Light from distant objects tend to be parallel and need less refraction to form a clear image.

The ciliary muscles are responsible for adjusting the shape of the lens. When they relax, the lens is less rounded. When they contract, the lens becomes more rounded.

Focusing on near objects requires greater effort than distance vision. When we view distant objects, the ciliary muscles are relaxed and the lens tends to remain thin. When we observe near objects, the ciliary muscles contract, forming the lens into a more rounded shape, bending the diverging rays more so that a clear image forms on the retina

Focusing is the result of accommodation. It is essential for the image to be focused to achieve clear vision. Accommodation allows humans to see both near and far objects clearly.

As a person ages the lens gradually loses its elasticity and can no longer accommodate for viewing close objects. Corrective spectacles are required.



Refractive power of lens in accommodation

At rest the lens is flattened and thin. Ciliary muscles are relaxed and the suspensory ligaments are taut. The focus of the eye is in the distance and the focal length is long. The refractive power is low. At maximum accommodation the lens becomes more rounded. The ciliary muscles contract and the suspensory ligaments are relaxed. The focal length is shorter and close objects are in focus. The refractive power is high.

Myopia and Hyperopia

Myopia

Short-sightedness.
When viewing a distant object the image falls in front of the retina. Those affected have difficulty seeing objects in the distance.

Causes:

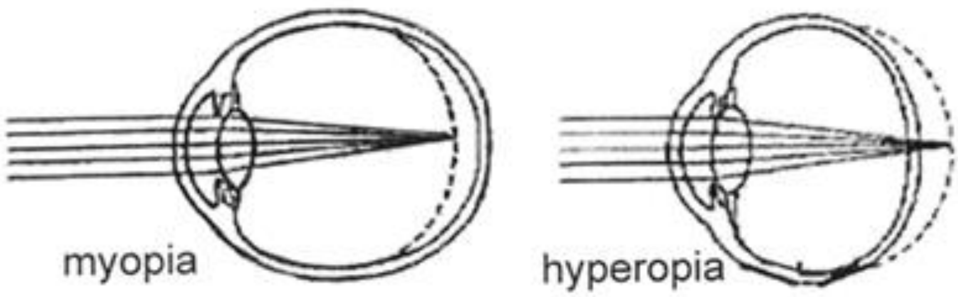
- Elongated eyeball
- Refractive power too weak to focus light on the retina
- Loss of lens elasticity.

Hyperopia

Long-sightedness.
When viewing a near object the image falls behind the retina. Those affected have difficulty seeing objects in close proximity.

Causes:

- Shortened eyeball
- The lens having poor accommodation ability (lens is too flat or unable to change shape sufficiently)
- Distance between lens and retina too short



Technologies to correct myopia and hyperopia

Spectacles

Spectacles are glass or plastic lenses placed in front of the eye in a frame.
For **myopia** patients the corrective lenses are concave compensating for the over refractiveness of the eye and allowing a clear image to fall on the retina.
For **hyperopia** patients the corrective lenses are convex, compensating for the weak refractive power of the eye and allowing a clear image to fall on the retina.

Contact Lenses

Contact lenses function on the principle of spectacles, being either convex or concave, but model the curvature of the eyeball and lie directly on its surface. Contact lenses can be glass, a soft plastic, or gas permeable, which are similar to the glass lenses but allow gaseous exchange between the surface of the eye and the outside air.

Refractive Laser Eye Surgery

Involves surgery to reshape the cornea.

Radial Keratotomy: Removes small slices off the surface of the cornea
Photorefractive keratotomy: Uses a laser to remove the outer membrane and surface of cornea which it reshapes.

Depth perception

Depth perception is the ability to judge the distance between objects. It requires 3D vision, which requires two sources of vision- binocular/stereoscopic vision.

The two different perspectives seen by the separate eyes allow an overlap between the fields of view. The brain can interpret the different signals and calculate the distance between objects by:

- Previous experience of the size of an object
- Parallax when moving the head- distant objects appear to move less than close objects
- Stereoscopic vision using the slightly different images from both eyes.

Animals with eyes on the front of their heads have binocular vision and therefore good depth perception. Eg. Cows, eagles, humans.

Animals that have eyes on the sides of their heads, eg. Sheep and horses, have a greater peripheral field of view to help escape predators but less depth perception.

PRAC 2- Modelling Accommodation

Convex lenses magnify images by causing rays of light to converge.
The lens in the human eye is a convex lens. When parallel rays of light are passed through a convex lens, they will converge at a point, known as the focal point.
The focal length of a lens is the distance of the focal point from the centre of the lens.
Distant objects will have the light rays travelling in an almost parallel manner. Close objects will have the light rays diverging from the light source.

1. Use a ray box kit with double convex lenses of various thicknesses
2. Pass triple beam through each lens and plot the path of each ray. Measure distance between centre of the lens and the focal point
3. Repeat with lenses of different thicknesses

Results: The thicker lens is used to help focus light from a nearby object.

Changes in the shape of the lens when focusing

Eye	**Shape of lens**	**Suspensory ligaments**	**Ciliary muscles**	**Focus**	**Focal length**	**Refractive power**
At rest	Flattened	Taut	Relaxed	Far objects	Long	Low
Full accommodation	Bulging and rounded	Relaxed	Contracted	Near objects	Short	high

Cataracts

A *cataract* is a clouding of the lens inside the eye; causing blurred vision and untreated can result in cataract blindness. The lens grows cloudy and eventually becomes opaque, preventing light from reaching the retina, causing total loss of sight.

Causes:

- Ageing
- Diabetes
- Glaucoma
- Detachment of the retina
- Rubella

Technologies to prevent cataract blindness

Cataract microsurgery:

Cataract microsurgery involves replacing the cloudy lens with an intraocular lens, usually involving local anaesthesia and light sedation. The most common technique is performed through making a 3mm incision where the cornea meets the lens in the sclera and a small probe at high frequencies is inserted into the eye, dividing the lens into small pieces, which then can be suctioned away before an artificial lens is inserted.

Implications for society

The Fred Hollows Foundation in Australia, set up in 1993, helped bring sight restoring eye surgery, which is inexpensive and only takes about twenty minutes, to remote indigenous Australian communities, as well as isolated communities in Nepal, Vietnam, Eritrea and Africa.

This organisation and the technology it uses has meant many people who were cataract blind can now see, being able to live longer, more independent and active lives. Society benefits from the knowledge, experience and wisdom of its older members, and spends less time, money and resources on caring for them.

The existence of cataract treatment doesn't mean all affected persons can benefit from it, with many communities too poor, remote or isolated to get surgery, and a limited number of surgeons trained to perform the surgery in third world conditions, and limited money and resources going towards projects like these.

4. The light signal reaching the retina is transformed into an electrical impulse

Photoreceptor Cells

The retina is a thin sheet of cells containing photoreceptor cells.

Rods and cones contain light sensitive photopigments. They convert light energy into electrochemical signals that the brain can interpret. Photopigments are proteins that change their structure when they absorb energy and this produces a nerve impulse.

Light coming from the front of the eye has to pass through two layers of neurones – bipolar and ganglion cells – before reaching the rods and cones. The nerve impulse created by the photoreceptors passes as an electrochemical signal along the bipolar and ganglion cells to the optic nerve.

Photoreceptor cells in the human eye

RODS:

- Very sensitive to light and allow vision in semi-darkness.
- Cannot detect different colours.
- Lack fine detail but show shapes and detect movements very well.
- Contain discs of visual pigment: rhodopsin.
- The retina apart from the fovea is less densely packed with photoreceptors and is entirely rod cells.

CONES:

- Three types of cone cells, sensitive to either red, blue or green light wavelengths. Combinations of these give you the perception of all the possible shades of colour you can see.
- Densely packed in the fovea region of the retina. This is where the image forms of whatever you are looking directly at. In good light, whatever you stare directly at will be seen clearly in full detail and colour.
- Densely packed and each cell has an individual nerve cell connection.
- Less sensitive than rod cells and require bright light.

Feature	**Rod Cells**	**Cone cells**
Number	125 million	7 million
Distribution	Not in the fovea, mostly on the periphery of the retina	Mostly in the fovea
Structure	Rod shaped end stacked with membranes containing photopigments	Cone shaped end shacked with membrane layers of photopigments Three different forms for colour vision
Function	• Night vision • Work in dim light • Do not detect colour	• Colour vision and visual acuity • Require bright light

Where the optic nerve leaves the eyeball there is a small 'blind spot' where there are no photoreceptor cells and you cannot see anything

Rhodopsins

Rhodopsin is a light sensitive pigment.

When a molecule of rhodopsin is hit by light it absorbs the light and undergoes photo-excitation. The molecule splits into two parts: retinal and opsin. This produces an electrochemical signal that travels to the brain via the optic nerve. The molecules reform as rhodopsin by enzymes and the process is repeated.

In bright light the rhodopsin in rods is broken down faster than it can be manufactured. In dim light production is able to keep pace with the rate of breakdown.

There are four photopigments in the human eye. All of them contain retinal but each has a different type of the protein opsin. Rods only contain one form of rhodopsin- visual purple- which is sensitive to blue-green light.

Cones

Humans have three types of cone cells:

- Red cones – respond to long wavelengths of light
- Green cones – respond to middle wavelengths of light
- Blue cones – respond to short wavelengths of light

Cone cells react when a particular wavelength of light hits them, and they send an impulse to the brain. The different combinations of cone cells that react are interpreted by the brain as different colours.

Colour blindness in humans

There are three colour sensitive types of cones in humans. Colour blindness in humans occurs because one or more of the three types of photopigments in cones is either absent or does not function properly. Complete inability to distinguish colours is rare. The most common form of colour blindness is the failure to discriminate between red and green. More common in males- genes for red and green cones are located on the x chromosome.

Photoreceptor cells in other animals

Animal	Visual system	Photopigment	Colour vision
Flatworm	• Cup eye with no lens • No image formed- only detects presence and direction of light • Photocells are ocelli, which produce an impulse when light falls on them	Rhodopsin	No
Bee	• Compound eye consisting of many ommatidia made up of a cornea and a lens made of a crystalline cone • Receptor cells produce an electrical impulse when light falls on them	Rhodopsin; able to detect motion very accurately	Yes, including ultraviolet
Octopus	Single-lens eye forming an image	Rhodopsin	Yes; also polarised light
Hawk	Single- lens eye forming an image	Rhodopsin; four types of cone cells	Yes; four colour visual system
Human	Single-lens eye forming an image	Rhodopsin; three types of cone cells and one type of rod cell	Yes; three colour visual system

Insect Vision: Insects have a 'compound eye'. Each eye is made of thousands of visual units called ommatidia. Each ommatidia is a self contained eye with its own cornea, lens and receptor cells. The image formed by a single ommatidium covers very little area, but each one is aimed in a slightly different direction. The insect's brain doesn't see a single detailed image but thousands of overlapping images covering almost its entire surroundings. This may lack detail but is excellent for detecting even the slightest movements

Flatworm Vision: It has 'eye spots'- nothing more than cup-shaped depressions lined with photoreceptor cells connected by nerves to the brain. There is no lens or cornea and no image is formed. Each eye merely informs the brain of light or darkness. The brain responds to this information by commanding the muscles to turn the animal towards darkness.

Use of colour for communication

Many animals use colour for communicating various types of information. The effectiveness of relaying this information relies on the recipient of the information having colour vision as well in order to detect it.

Animals may use colour for:

- **Signalling sexual availability** – for example, the genital area of female baboons turns red during ovulation
- **Mating/courtship behaviours** – the bird of paradise sports colours to attract mates
- **Threat signals** – for example, the poisonous dart frog uses colour to signal predators they are not good to eat
- **Sexual dimorphism** in many birds
- **Mimicry –** many non-poisonous species of insects use mimicry to communicate to a predator that they are poisonous
- **Camouflage –** eg. Chameleons to stay hidden from predators or prey.

Some cephalopods have specialised skin cells that change colour and reflectiveness. The blue ringed octopus uses its iridescent blue colouring only when it feels threatened or as a warning when it is about to attack, and cuttlefish use colour displays to attract females.

Occurrence of colour vision in animals:

Animals that are known to possess colour vision include bony fish, frogs, turtles, lizards and birds. In mammals, with the exception of primates, colour vision is rare.

Using colour for communication only proves effective if the animal receiving the message has colour vision. Mammals with poor colour vision rely more on their senses of smell and hearing for communication purposes.

Birds, which rely heavily on colour for communication, have more cones for seeing colour, being tetra chromatic, in comparison to humans who are trichromatic.

Colour is also important for the symbiotic relationship between bees and flowers, which are colourful specifically to attract bees, which have good colour vision for the purpose of detecting pollen.

5. Sound is also a very important communication medium for humans and other animals

Usefulness of sound

Useful because of the enormous variety of sounds that can be produced – actual sound, loudness, pitch or duration.

- Easily produced at any time
- Can be easily varied to produce different calls to have different meanings
- Does not rely on day or night, or on transparent substances to travel through
- Travels easily from one place to another as long as there is a medium for transmission
- Travels long distances
- Doesn't have to be visible to the receiver and can travel around corners

How sound is produced

Sound is a form of energy caused by a vibration- an oscillation- when an object vibrates it produces a series of disturbances in the particles surrounding it, caused by the changes in pressure.

Sound travels fastest through solid, then liquid and then gas. Cannot travel in a vacuum- must have a 'medium' to carry the vibrations.

Sound energy is formed when an object vibrates. This causes the air molecules next to the object vibrates at the same frequency. Other molecules in contact pick up the vibration and cause a compression wave which travels through the medium. The frequency of the vibration remains the same as that of the original vibrating source.

If sound waves are detected by a sensor, such as when they push against the eardrum then the sound waves are 'heard'.

Wavelengths: A sound wave is a cycle of alternating compressions and rarefactions- one of these cycles is a wavelength.

Frequency: The number of times it vibrates each second. Measured in hertz. A sound that vibrates at a high frequency is said to have a high pitch – a sound that vibrates at a low frequency is said to have a low pitch. Sound waves do not change frequency when they are transmitted.

Pitch: Changed by either the wavelength or the frequency.

Amplitude: Loudness- measured in decibels. The further the peak of the wave moves from the midpoint, the louder it is.

Human larynx

- Larynx
- Vocal cords
- Tongue
- Soft palate
- Nasal cavity

The lungs and muscles attached to the lungs provide the volume of the sound.

The larynx is located below the tongue and soft palate in the front of the neck. The larynx has a ring of cartilage surrounding two vocal cords. Sound is produced by the vocal cords vibrating. The vocal cords are muscular and they can alter the pitch and volume of the sound by changing shape.

Humans can produce many different sounds by changing the shape of the passage that the sound passes through. Movement of the lips, tongue, soft palate and jaw all result in changes to the sound produced.

PRAC 3 – Wavelength, Frequency & Pitch

Aim: To determine the relationship between wavelength and frequency and pitch of sound.

Method: Use a cathode ray oscilloscope (CRO) and audio oscillator to generate and detect sound waves of varying frequencies. Using tuning forks demonstrate that higher frequency notes produce a higher pitch of sound.

Conclusion:

Lower pitch = lower frequency = larger wavelength
Higher pitch = higher frequency = higher wavelength
Frequency of a sound is related to its pitch and frequency and wavelength are inversely related: as one increases the other decreases.

Structures used to produce sound

FISH:
No lungs or larynx.
Swim bladder- a gas filled sac. Many fish can use the muscles of their swim bladder to cause it to vibrate to produce sounds. Other fish produce clicking sounds with their fin or gill covers.

INSECTS:
No lungs or larynx.
Insects breathe largely by diffusion of gases through tiny tubes throughout their body.
Crickets and grasshoppers make sounds by rubbing legs or wings together so that some part of their body structure vibrates producing sound waves.
Cicadas produce sounds in a similar way, then amplify it using hollow spaces in their abdomen, which act as resonance chambers.

6. Animals that produce vibrations also have organs to detect vibrations

Detection of vibrations

INSECTS:

Antennae of a male mosquito vibrates and sends messages to his brain if soundwaves of a particular frequency are detected – the sound made by the wings of the female mosquito vibrating.
Crickets and grasshoppers have tiny plates of membrane (like an eardrum) which vibrate when struck by sound waves. Messages are sent to the brain. Membranes are located on legs, abdomen or base of wings.

FISH:

Sound travels faster in water than air so fish have ears on the inside of their body as the sound passes easily through the body to two internal ears.

Three main systems:

1. A labyrinth that contain sound receptors- inside their head, detect sound waves.
2. A visible lateral line that runs along the body and contains receptors sensitive to changes in pressure in the surrounding water.
3. Swim bladder- in some fish the swim bladder vibrates and the vibration is transferred to an internal ear.

MAMMALS:

Hearing is most developed in mammals.
External ear to detect vibrations, middle ear to transmit the vibrations and the inner ear containing the cochlea, the main hearing organ.

	Insects	Fish	Mammals
Structures used to detect vibrations	Tympanic membranes, sensory hairs	Internal ear, lateral line system, swim bladder	Cochlea
Receptor cells	Mechanoreceptor cells	Hair cells in the inner ear; neuromasts in the lateral line	Hair cells in the organ of Corti
Medium transmitting sound	Air, solid (ground or leaves)	Liquid-water	Air or liquid

Human ear

Two functions:

- Detecting sounds
- Maintaining physical balance

Outer ear:
Consists of the fleshy external PINNA and the ear canal that leads to the TYMPANIC MEMBRANE. The pinna collects sound waves and channels them as well as giving information about the direction of the sound.

Middle ear:
Consists of three tiny ear bones called ossicles: HAMMER, ANVIL and STIRRUP
Hammer is attached to the tympanic membrane, when this vibrates, the signal is sent though the ossicles, which acts as levers and magnify the signal.
The stirrup is attached to the OVAL WINDOW. This membrane vibrates and pushes on the fluid in the inner ear.
The ROUND WINDOW is just below the oval window and bulges outwards to allow the fluid in the cochlea to move

Inner ear:
Consists of the SEMICIRCULAR CANALS associated with balance, and the COCHLEA, a long, narrow, coiled tube separated into three parts by two membranes: REISSNER'S MEMBRANE and the BASILAR MEMBRANE.

The ORGAN OF CORTI contains the sound receptor hair cells and is on the basilar membrane. Each hair cell has STEREOCILIA in contact with the TECTORIAL MEMBRANE. The stereocilia touch the tectorial membrane where the basilar membrane flexes. A signal is sent to the brain via the auditory nerve, made up of the axons of the neurones attached to hair cells.

The amplitude of the sound waves determines volume; the greater the amplitude, the more vigorous are the vibrations in the cochlea and the hair cells bend further; this is interpreted by the brain as greater volume.

EXTERNAL EAR	**pinna**	Funnel of the outer ear- comprises folds of skin over cartilage	Gathers sound waves and channels them down the ear canal. Helps determine direction of the sound and protects the internal parts.
	Ear canal	Tube leading from pinna to tympanic membrane	Channels the sound wave towards the tympanic membrane. Produces a waxy substances to protect and lubricate the ear.
	Tympanic membrane	Eardrum- sensitive membrane situated between the external and middle ear	Vibrates when sound waves strike
MIDDLE EAR	**Ear ossicles**	Three small bones of the middle ear. Hammer(malleus), anvil(incus) and stirrup(stapes)	Transmit the vibration of the eardrum across the middle ear to the oval window. Acts as a lever to reduce amplitude. Amplifies force of vibrations
	Oval window	Small, thin membrane	Receives the vibration from the tympanic membrane via the ossicles at a much greater force.
	Round window	Membrane just below the oval window	Acts as a piston bulging in ad out transferring the vibrations from the oval window to the fluid in the inner ear. Allows vibrations to escape again from the cochlea- prevents wave reflections within the cochlea which could create reverberations and a constant 'ringing' in the ear.

O U T E R E A R	**cochlea**	Fluid filled spiral structure. Long tube wound around itself filled with liquid	Sound waves are transmitted as pressure waves in the fluid where they stimulate the organ of corti
	Organ of corti	In the cochlea- contains millions of receptor hair cells attached to nerves	Hairs are tuned to certain wave frequencies. When the wave passes over the hairs an electrical signal is triggered.
	Auditory nerve	A bundle of nerve fibres bound together	Sends the electrical signals to the brain to be interpreted.

Eustachian Tube

Part of the middle ear. Connects the middle ear to the nose and throat and keeps the pressure in the middle and outer ear equal. Also drains fluid from the middle ear. Normally the canal of the Eustachian tube is closed, but when you yawn, cough or swallow it opens briefly and the air from the outside is equalised with the air in the inner ear.

Pathway of sound through ear

Sound travels as a pressure wave made up of alternating compressions and rarefractions of molecules. When these vibrations reach the eardrum the sound energy is converted into mechanical energy by the movement of the eardrum and the ossicles in the middle ear. This mechanical energy travels through fluid in the cochlea and bends hair cells in the organ of corti. The hair cells convert the mechanical energy into an electrochemical signal that is transmitted to the brain via the auditory nerve.

Pinna → auditory canal → <u>tympanic membrane → ossicles → oval window → cochlea</u> → *hair cells* → *auditory nerve* → *brain*

- **Sound energy**
- <u>Mechanical energy</u>
- *Electrochemical energy*

Hair cells in corti & detection of sounds of different frequencies

The hair cells in the organ of corti are connected to the structure by hairs of different lengths. Each different length fibre will only vibrate, and distort the membranes, in response to vibrations of a particular frequency.

Sound waves travel through the cochlear fluid as pressure waves of various frequencies, according to the sound frequency which entered the ear.

The result is that each sound frequency only stimulates SOME of the hair fibres to vibrate and set off a nerve signal. The brain interprets these signals as hearing sounds of different pitch, according to which hair cells sent the message.

Upper region of the organ of corti- fibres longer- respond to lower frequencies.
Near the base of the cochlear spiral- fibres shorter- respond to higher frequencies.

Role of sound shadow cast by the head in the location of sound

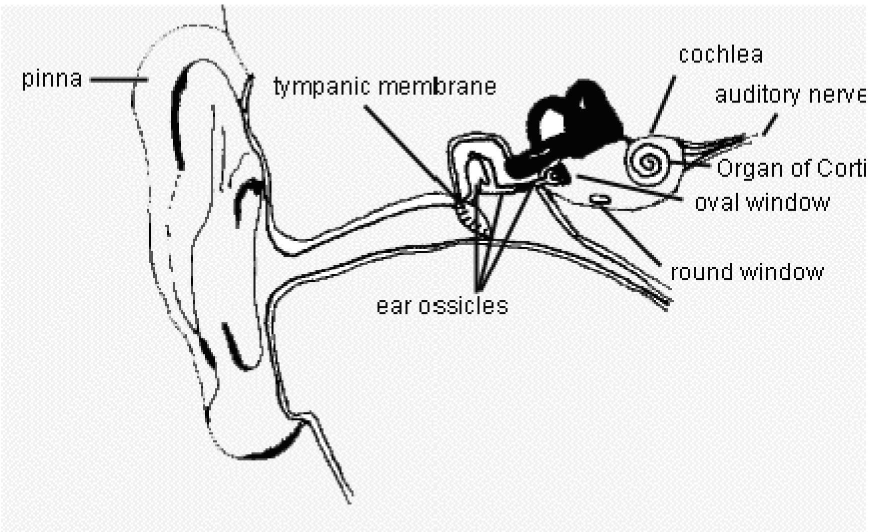
Humans and other animals use two methods to locate the source of sound:

- The difference in time between the sound arriving at each ear
- The difference in the intensity of the sound arriving at each ear

Differences occur because the head casts a sound shadow that causes one ear to receive less intense sounds than the other.

Humans usually trace the location by turning their heads until the intensity of the sound is equal in both ears so they look at the source. Other animals have mobile ears that will turn to pick up a sound.

Mammalian ear



Range of frequencies detected as sound

Mammal	**Range of sound detected and possible reasons for the difference**
Human	20-20 000 Hz
Bats	100 000- 120 000 Hz. High frequency sounds allow for precise echo location.
Porpoise	50- 150 000 Hz- Marine mammals need to communicate over large distances underwater, which low frequency sounds are effective for

Dolphins and bats hear sounds at extreme high frequencies- use them for navigation and prey detection- SONAR and echolocation.

Humpback whales communicate over very long distances through low frequency waves.

Low frequency waves also travel through the ground well, so burrowing animals such as moles are sensitive to these vibrations.

Nocturnal animals are often very sensitive low frequencies. Kangaroo Rats are very sensitive to sounds of low frequencies, for example the wing beats of a hunting owl. The rat survives by hearing its enemies approach.

Hearing aids & Cochlear Implants

Hearing aids and cochlear implants are both devices designed to improve deafness.

Device	Hearing condition	Type of energy transfer	Advantages	Disadvantages
HEARING AID	Damage to outer or middle ear	Sound → electrical → amplified sound energy	• Relatively cheap • No surgery required	• Will not restore normal hearing • Also amplifies backgroun d noise • Need to adjust to sound level • May cause pain
COCHLEAR IMPLANT	• Profound deafness • Damage to inner ear or auditory nerve	Sound → electrical	• Provides hearing to profoundly deaf people • Restores hearing after injury	• Surgery is expensive with potential post-operative side effects such as infection and facial nerve damage • Need to learn to interpret sounds.

Hearing Aids:

For Partial hearing loss due to:

- Small bones in the middle ear are damaged or have fused together, not carrying sound vibrations to the cochlea very well. The actual receptors are working but the vibrations are not being conducted to them properly.
- Hair receptors in the cochlea are damaged and they have lost their sensitivity. They still work, but require a louder sound to reach the 'threshold' at which they respond.

A hearing aid consists of a miniature microphone and amplifier system. It picks up sound and sends amplified sounds down the person's ear canal. Usually the device only amplifies the sound frequencies most commonly used for speech, and ignores the background noise frequencies.

The patient can be tested to determine which precise frequencies they are most sensitive to.

Sound →electrical signals →sound (louder, at selected frequencies)

Limitations:

- Cannot help profoundly deaf
- If the hair cells are not responsive or the auditory nerve is unable to conduct a nerve message, then deafness may be total and no amount of amplifying sound will help.

Cochlear Implants:

Some people are born totally deaf, or become profoundly deaf due to an infectious disease or an inherited disorder in which the receptor hair cells of the cochlea die.

A cochlear implant involves an electronic device being implanted into the skull, with one or more electrodes connecting it to the auditory nerve.

Sounds are picked up by a microphone and electronically analysed by a processor unit. This converts the sounds into a set of electronic signals transmitted as radio waves through the flesh to the cochlear implant (placed in the skull through surgery). Electrical signals are carried by an electrode and stimulate the auditory nerve, which fires nerve signals to the brain.

The brain interprets these nerve signals as the hearing of sounds, but these won't be the same sensation as in normal hearing. The patient will need to learn how to interpret the sensations like having to learn a new language.

Sound → electrical signals (microphone & processor) → radio waves (transmitter) → electrical signals (implant & electrode) → nerve signals (auditory nerve)

Limitations:

- Expensive
- Adults who became deaf after learning to speak are often helped, but those born deaf and given an implant as adults rarely learn to interpret the new sensations. They have learnt to cope with deafness and often do not benefit from a cochlear implant
- Children born deaf can learn to hear and speak but it takes tears of training and therapy
- If there is damage to the auditory nerve as well as the cochlea, the implant cannot stimulate a signal that can get to the brain.

Future Research:

- How to reproduce sound better using electrical stimulation
- How to make cochlear transplant invisible
- Use of nerve growth factors to protect healing nerve from dieback after deafness
- Development of drugs that can regenerate dead hair cells inside the cochlea
- Implants for patients with damaged auditory nerves
- A cure for hereditary hearing loss

7. Signals from the eye and ear are transmitted as electro-chemical changes in the membranes of the optic and auditory nerves

Nerves

Neurone: a single nerve cell. Elongated. Electrical impulses are passed from one end of the neuron to the other. Neurons do not make physical contact with each other – the space in between them is the synapse. When the electrical impulse that carries the message along the neuron reaches the end of the neuron it is converted into a chemical known as a neurotransmitter, which travels across the synapse to the next neuron.

STRUCTURE	FUNCTION
Dendrites	Receives the signal from the previous neuron
Cell Body	The largest part of the cell containing the organelles
Axon	Long projection that conducts the electrical signal away from the cell body
Myelin Sheath	Insulates the axon so that the electrical signal can be transported quicker along the neuron
Axon terminals	Line up next to the dendrites of the next neuron, neurons or target cells such as muscle cells, where the signal leaves the neuron.

- *Sensory neurons*- perceive or sense information from the internal and external environment and relay the message to the central nervous system.
- *Motor neurons*- conduct message from the central nervous system to the effector cells.
- *Interneurons*- found in the central nervous system and communicate only with other neurons

Neuronal fibre: series of neurones joined end-to-end, forming a single pathway for signals to be carried

Nerve: a bundle of neuronal fibres, all connecting a part of the body to the brain.

A neurone is made of dendrites, a cell body containing the nucleus and an axon. The axon branches of one neurone join with dendrites of other at synapses. The long axon fibre is usually covered in a myelin sheath that insulates the fibre.

A nerve bundle is a bundle of neuronal fibres or axons. Blood vessels supply blood, and connective tissue helps hold the fibres together. Neurones require considerable energy and nutrients to operate.

Neurones

Neurones are nerve cells that transmit signals by electrochemical changes in their membranes. The signals travel like a wave- 'wave of depolarisation' from dendrites, through the cell body to the axon and then have to cross synapses to other neurones.

The electrical chargers involved are Na+ ions flowing into the cell at right angles to the movement of the signal. Between signals, Na+ ions are pumped out of the cell, creating an electrical difference between inside and outside of the membrane- polarised. When the neurone 'fires' a region of the membrane suddenly becomes permeable to Na+ ions. They flood inwards, depolarising that part of the cell. This sets of the next region of the membrane, so the nerve signal travels the length of the neurone as each section depolarises.

Nerve threshold and action potential

A neurone will not fire at all unless it receives a certain minimum stimulus – **Threshold:** is the minimum stimulus required to generate a response in the nerve cell.

This prevents insignificant events, or tiny accidental stimuli from causing signals which could overload the system.

The conduction of a nerve signal is an all or nothing situation.

Areas of cerebrum involved in the detection and interpretation of light and sound

Visual Cortex: Area where signals from the eyes are received and interpreted.

Auditory cortex: Area where signals from the ears are received and interpreted.

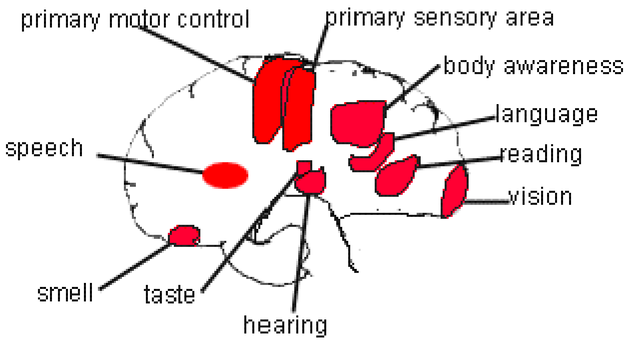
Speech Centres: Areas where you choose words and make sentences and understand what others say to you.

Cerebrum: Memory, senses and conscious command centres. Divided into right and left. Largest part of the brain and contains small grooves and folds and has a rich supply of blood.

Medulla Oblongata: Automatic functions eg. Heartbeat

Cerebellum: Co-ordination

Major structure	Composing structure	Function
CEREBRUM	Frontal lobe	Related to learning, thoughts, memory and speech; the speech section is located in Broca's area where sound is investigated
CEREBRUM	Parietal lobe	Processes speech in Wernicke's area
CEREBRUM	Occipital lobe	Processes visual signals where light and vision is perceived
CEREBRUM	Temporal lobe	Processes auditory information, where hearing is perceived
CEREBELLUM		Coordinates sensory signals and helps with balance, movement, coordination and processing of language
MEDULLA OBLONGATA		Relays signals between the brain and the spinal cord.



Interpreting signals for the coordination of behaviour

You need to make sense of a signal in order to make an appropriate response to benefit you. Interpretation of a signal can be very subjective- the brain makes sense of an incoming sensory signal due to its memory of past experiences. While some behaviours are innate, others are learned.

If there is damage to the visual part of the brain, objects may seem larger or smaller than they really are, they may appear to be the wrong colour and hallucinations may occur.

Damage to the temporal lobe may result in the inability to understand words or construct sentences.

Face blindness occurs after damage to the occipital lobes.

Brain damage through accident or disease can result in the inability to correctly interpret the information coming from the sensory organs, making coordination of behaviour difficult because the incorrect information will be acted upon.

PRAC 4 – Nerve & Neuron slides

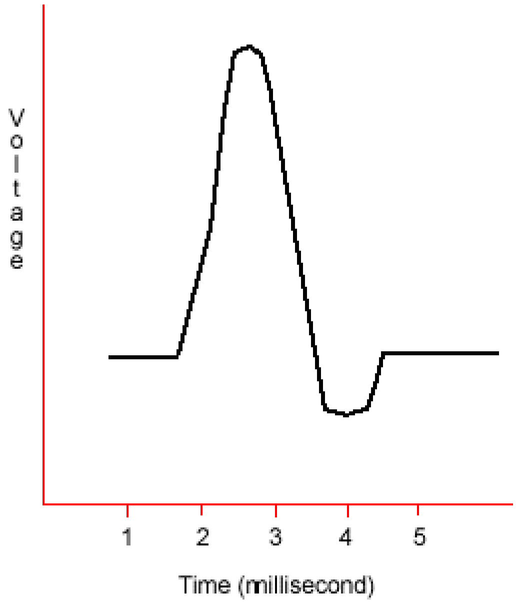
We observed electron micrographs that showed cell bodies with star like protrusions that extended into the lengthy axons or shorter dendrites.

Typical action potential

The electrochemical changes in the nerve cell membrane involve the relative movement of sodium and potassium ions across the membrane.

At rest, the movement of ions is balanced but the membrane has a difference in electrical charge- the outside is positively charged.

When a stimulus is received, if it is sufficient to change the potential of the membrane, the membrane changes its permeability and the threshold is achieved. This allows rapid flow of ions and hence an action potential initiates. This then travels as a wave along the membrane surface from the points of stimulus.



PRAC 5 – Brain dissection

Cerebrum: The folded material at the top and front of the brain. Controls conscious thinking, including messages from the sensory receptors and sending messages to receptor organs.

Medulla Oblongata: The swollen upper end of the spinal cord below the pons. Upper extension of the spinal cord and part of the hind brain; controls basic functioning such as breathing.

Cerebellum: The convoluted lobe at the rear base of the brain. Behind the brain stem; part of the hard brain; coordinates movement, posture and balance.

PART OF CEREBRAL CORTEX	LOCATION	FUNCTION
Visual cortex	Occipital lobe at rear of brain	Detection of simple visual stimuli. Perception of light
Visual association area	Above the visual cortex	Complex processing of visual information. Interpreting light
Auditory Cortex	Temporal lobe at lower side of brain	Detection of sound (loudness and tone) perception of sound
Auditory association area	Behind the auditory cortex	Complex processing of auditory information. Interpreting sound
Broca's area	In the frontal lobe of the cortex	Speech production, language processing

Safety:

- Correct footwear
- Minimise hazards
- Care taken when using sharp utensils
- Use rubber gloves and dispose at end
- Make sure all waste products of dissection are wrapped well and placed in the garbage.