OCR (B) Biology A-level

5.2 Nervous control

Notes

5.2.1 Nervous system

The brain

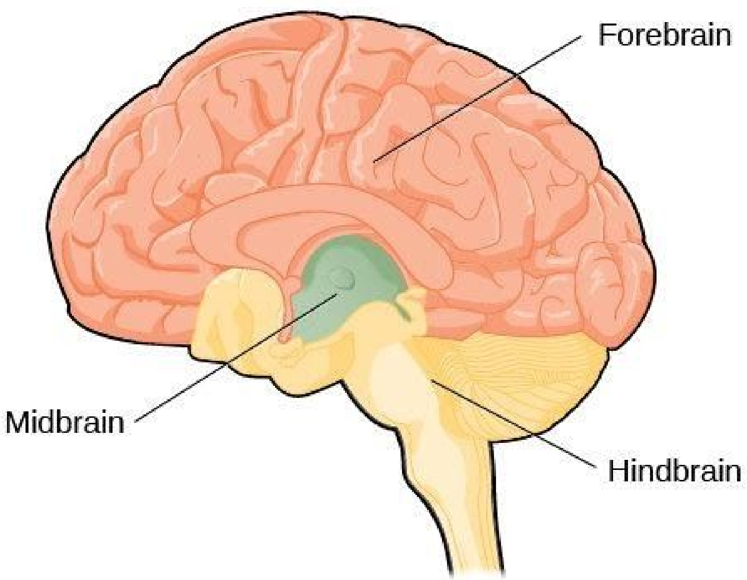
Structure of the human brain:

The human brain **weighs approximately 1300-1400 grams.** It is made up of 100 billion neurones. The brain is protected by the skull/ cranium and encased in membranes called **meninges.** Inflammation of the meninges can result in meningitis. The brain contains **4 ventricles**, these are filled with cerebrospinal fluid (CSF). **CSF** is important for nutrition as it contains glucose and oxygen. It also **protects** the brain against shocks or trauma alongside maintaining the pressure in and around the brain.

The **cerebrum** is enlarged in comparison to other structures within the brain. This enables increased cognition. **The cerebral cortex** forms the outer layer of the cerebrum. It is highly folded to increase the surface area of the brain without increasing its volume. This allows the brain to fit within the bony skull/cranium.

The brain may be divided into three main areas:

1) **Forebrain** – contains the hypothalamus, thalamus and cerebrum (divided into lobes)
2) **Midbrain** – network of nerve fibres which connect the forebrain to the hindbrain
3) **Hindbrain** – contains the medulla oblongata (as part of the brainstem) and the cerebellum.



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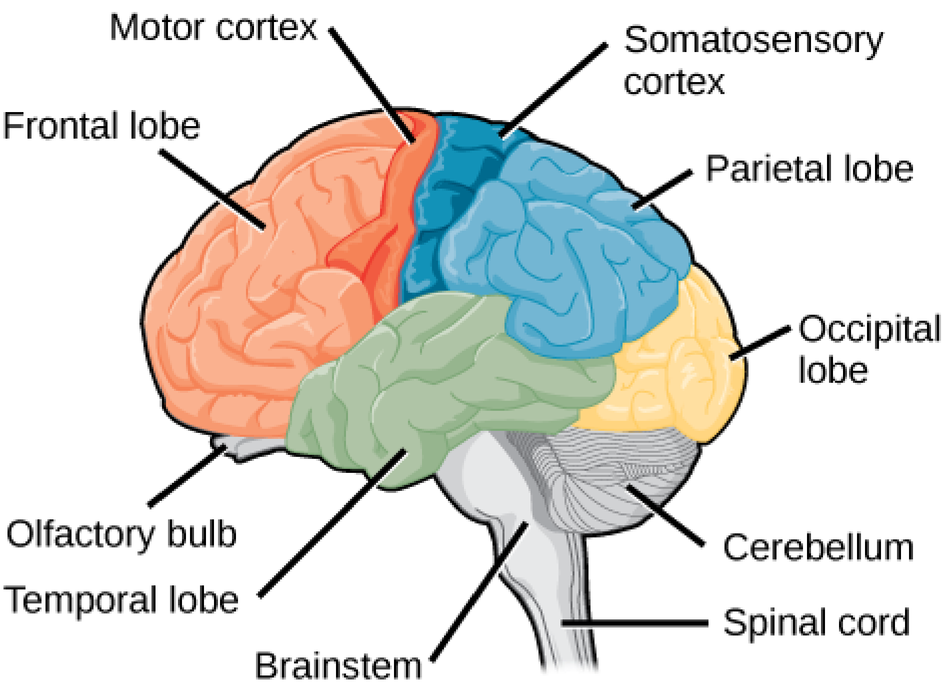
Function of brain structures:

- **Cerebrum –** formed of **two hemispheres** that are responsible for higher-order functions and complex skills. These include memory, speech, cognitive thought, problem-solving, attention and emotions. It is the source of **intellectual function** in humans, and more developed in comparison to other animals.

The cerebrum is formed of lobes:

- **Frontal lobe:** includes **Broca's area** involved in speech alongside the site for reasoning, planning, emotions and problem solving
- **Parietal lobe:** sensory area; visuo-spatial processing
- **Temporal lobe:** includes **Wernicke's area** involved in speech; plays a role in learning, memory, sense of sound and processing complex stimuli i.e. faces
- **Occipital lobe:** contains primary visual cortex associated with vision



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- **Hypothalamus –** part of the forebrain which contains general functions of daily life e.g. body temperature, blood solute concentration, hunger, thirst and sleep. It is the main controlling region of the autonomic nervous system. The hypothalamus is important **in regulating the secretion of hormones** from the pituitary gland (i.e. luteinizing hormone [LH], follicle stimulating hormone [FSH], thyroid-stimulating hormone and adrenocorticotropic hormone) through its direct connections. The regulation of the endocrine system relies on the functioning of this relationship.

- **Thalamus –** part of the forebrain that acts as a **relay centre** – i.e. sending and receiving impulses to and from the cerebrum.

- **Cerebellum –** part of the hindbrain that **coordinates the precision and timing** in muscular activity. It contributes to balance and posture and learning of motor skills.

- **Medulla oblongata –** forms part of the **brainstem**. Controls the important centres required to maintain breathing rate, heart rate and blood pressure.

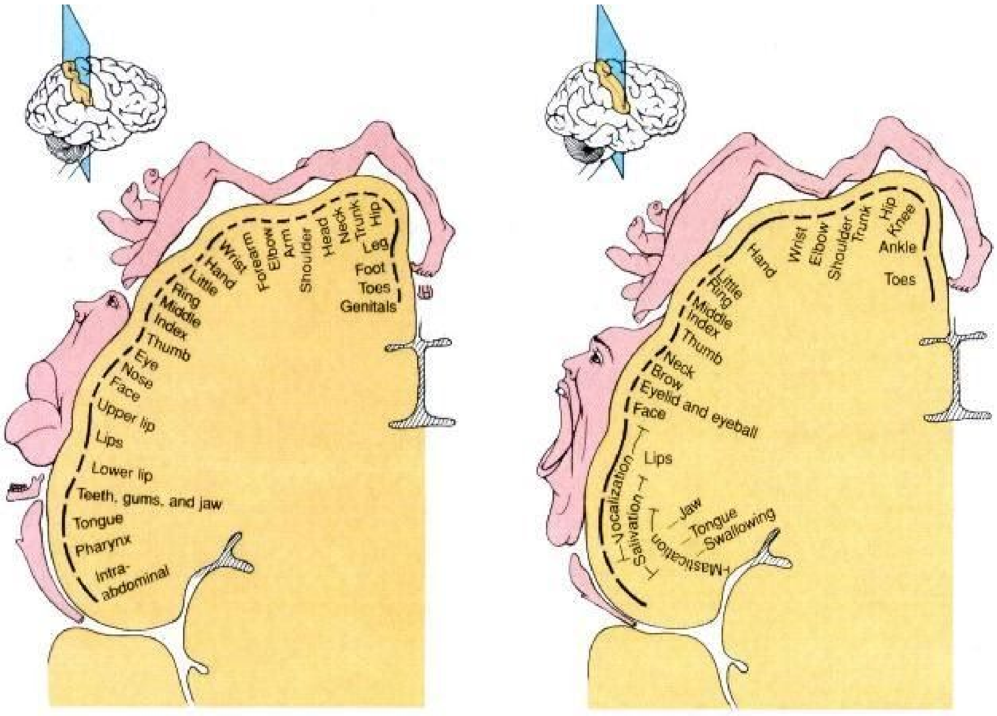
- **Wernicke's area –** controls the **comprehension of written and spoken language** – i.e. speech processing and understanding language.

- **Broca's area –** motor control of speech; deals with grammar – i.e. production of coherent speech

The Human Homunculus

The **central sulcus** divides the frontal and parietal lobes.

The primary sensory and motor areas are located on either side of the central sulcus. These regions are **somatotopically organised** – i.e. information from a specific area of the body is represented within a certain area of the cortex. This can be portrayed using the model of the **human homunculus** (*Latin:* 'little man'). The resulting image shows a disproportionate appearance of the different parts of the body. The homunculus has larger lips, huge hands and face in comparison to the rest of the body. This represents the fine motor skills and greater density of sensory nerve fibres found in these particular parts of the body. Parts of the body which require fewer sensory/motor connections to the brain appear smaller.



(a) Somatosensory cortex in right cerebral hemisphere
(b) Motor cortex in right cerebral hemisphere

Image source: thebraingeek.blogspot.com

Autonomic Control

The human nervous system is organised into subdivisions.

Overall, the nervous system may be **divided into the central nervous system (CNS) [involving the brain and spine] or the peripheral nervous system (PNS).** The PNS has further divisions – i.e. the **sensory** and **motor** pathways. The motor pathway may be voluntary (i.e. somatic) or involuntary (i.e. autonomic).

The medulla oblongata, which forms part of the brainstem, is responsible in the coordination of involuntary (or autonomic) activity. The **autonomic nervous system** is further divided into **sympathetic** and **parasympathetic**. The parasympathetic and sympathetic system act in antagonism to maintain homeostasis. Involuntary activities including breathing, heart rate and digestion.

Sympathetic Nervous System – '*Fight or Flight*'

The sympathetic division regulates the mobilisation of the body systems/ energy stores. It is often described as the **'fight or flight' response** and is especially useful whilst dealing with danger. Activation of the sympathetic nervous system results in the release of the neurotransmitter**, noradrenaline.**

- Dilatation of pupils in eye – adaptation to the dark
- Decrease in blood flow to the gut; reduced digestion;
- Increase in breathing rate;

- Increase in heart rate
- Stimulate the release of glucose – increase energy for 'fight'

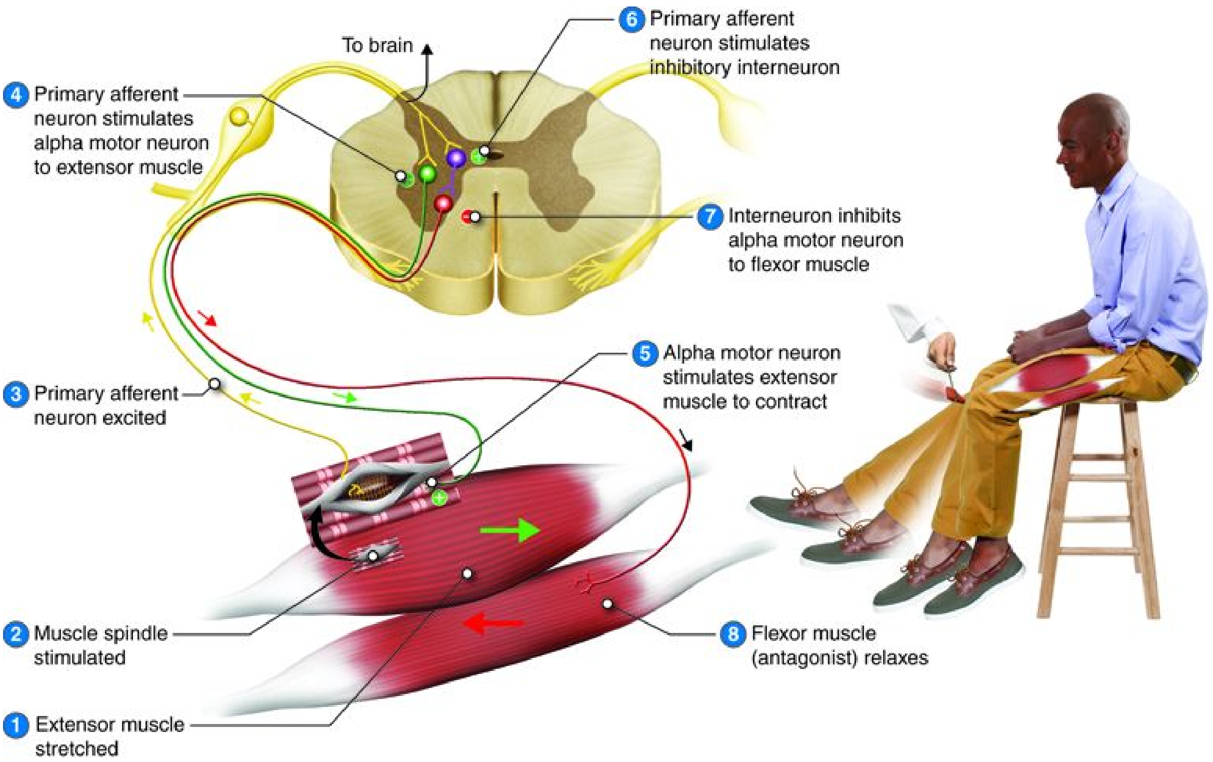
Parasympathetic Nervous System – 'Rest and Digest'

The parasympathetic division regulates the body's processes during **resting and digestion phase.** Therefore, many of its functions are inhibitory. Its activities are mediated via the neurotransmitter, **acetylcholine.** For example, the **vagus nerve** provides parasympathetic innervation to the thorax and abdomen.

- Constriction of pupils in eye
- Reduction in heart rate
- Reduction in breathing rate
- Stimulation of digestion
- Inhibition of glucose release – conservation of energy

Reflexes

Stretch reflex



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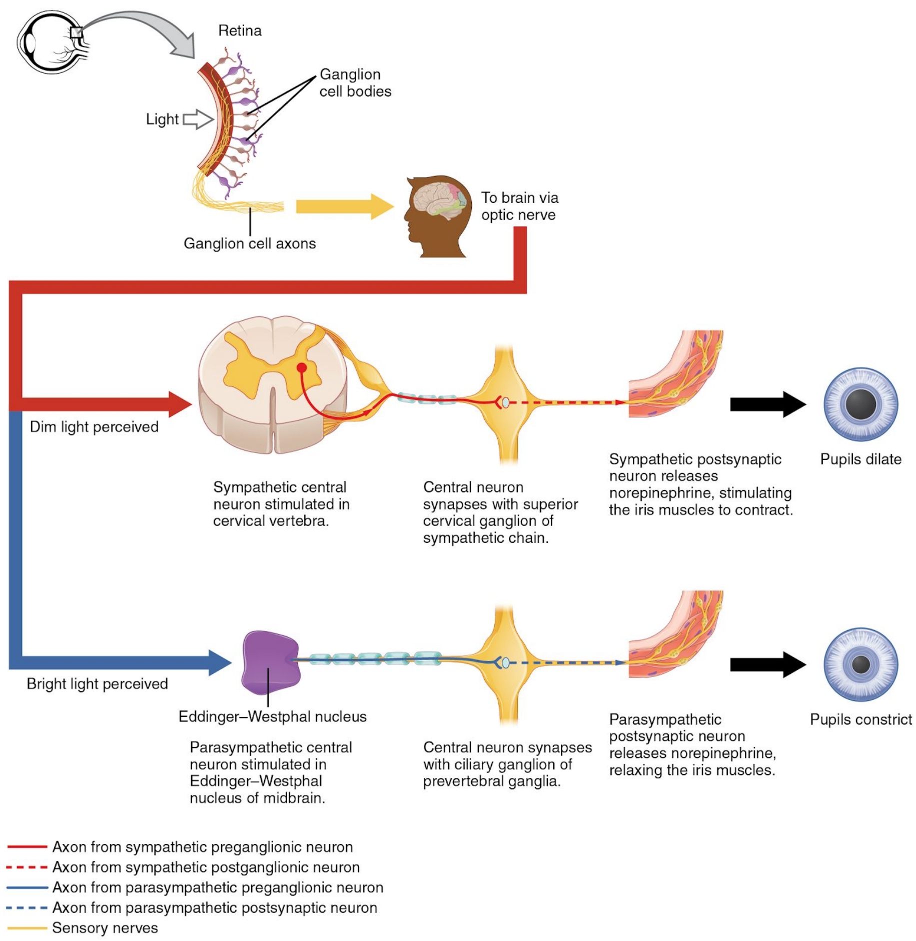
Blink reflex

The blinking reflex acts to protect the cornea when it is touched by a foreign object. The reflex actually results in **both** eyelids closing (consensual response).

- The sensory neurone carries an impulse (fifth cranial nerve) in response to the cornea being stimulated.
- The relay nerve (located in the lower brain stem) then passes this impulse onto a motor neurone (seventh cranial nerve).
- This impulse along the motor neurone is then passed on the muscles in the eyelids which then close.

Iris reflex



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Imaging:

There have been advancements in the use of non-invasive, radiological techniques to appreciate the anatomy and pathology of the brain. Such modalities include functional magnetic resonance (fMRI), computed tomography (CT), positron emission tomography (PET) and electroencephalography. **The choice of imaging modality** depends on the clinical question – i.e. CT scan may be required whilst excluding a stroke, whereas EEG is useful for identifying electrical activity in epileptic seizures.

- **CT –** identification of internal structure in slices; high resolution of bone, soft tissue and blood vessels; detection of brain injuries and skull fractures; the high exposure to **ionizing radiation** by a CT scan may lead to the development of cancer

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- **MRI –** imaging using a **strong magnetic field**; detailed anatomical image without the use of ionizing radiation; not for use in individuals with metallic devices such-as pacemakers; identification of brain structures – i.e. brain tumours.
- **fMRI –** imaging using a magnetic field to **record changes in blood flow**; study the structure and function of the brain in real time.
- **PET –** detection of biochemical changes in the brain according to **uptake of glucose in brain areas**; uptake of glucose is directly related to the blood flow and hence activeness of regions of the brain; useful in the imaging of tumours.

- **EEG –** electrodes placed on the scalp **detect voltage fluctuations**; non-invasive technique, showing activity within the cerebral cortex – useful in diagnosis of epilepsy.

Brain development and neuroplasticity:

Brain development begins shortly after conception from a structure called the **neural tube**. The tube closes at three weeks of gestation and develops into the brain. At birth, the brain contains more than 100 billion neurons.

The neural tube is made up of two types of cells:

1) **Neurons** – brain cells responsible for communication
2) **Glial cells** – support cells

Neurons migrate to various regions of the brain to perform specific tasks – i.e. some go to the occipital lobe to become visual neurones.

Ages 0 to 3 (i.e. the first part of life) are a crucial time for the development of learning and language acquisition. Environmental factors such as good stimulation and care are required for development, otherwise speech and cognitive function may lag behind average. Delays in development must be acknowledged as intervention **after the first 6 months** may render worse outcomes.

During this time, synapses are formed rapidly. These allow development of sensory pathways, language ability and higher cognitive function. These peak within the first year of life.

Brain development continues at a slower rate in teenagers and adults. During this period, synapses may strengthen or weaken, and areas of the cortex may be remapped. This change in synapse communication and structure of the brain overtime is known as neuroplasticity. Factors such as the environment, thoughts, emotions, brain injury and specific patterns of learning or activity can contribute to neuroplasticity.

Gene expression and the brain

Determinants of gene expression include:

- Methylation
- Histone modification

Gene expression governs the development, function and health of the brain.

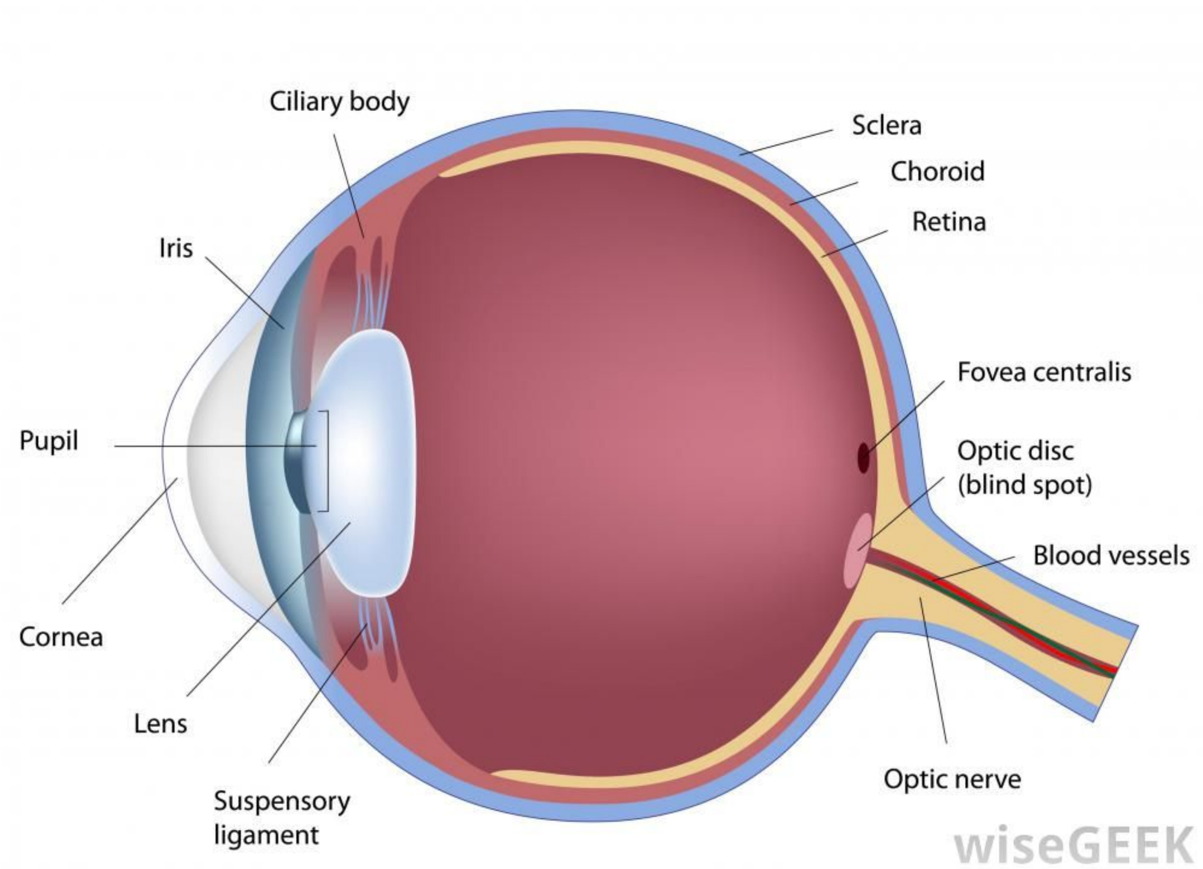
Individuals with psychiatric conditions are known to have over 60 **epigenetic markers** as compared to healthy individuals. For example, a lower methylation of a gene may contribute to the development of **schizophrenia**. This gene functions in early development of the brain which may later impact learning and behaviour in adulthood.

The gene expression of an individual may become apparent when illicit drugs such as cocaine are used. The altered gene expression by the brain may contribute to increased susceptibility of drug abuse, addiction and relapse. These are complications which occur due to drug use.

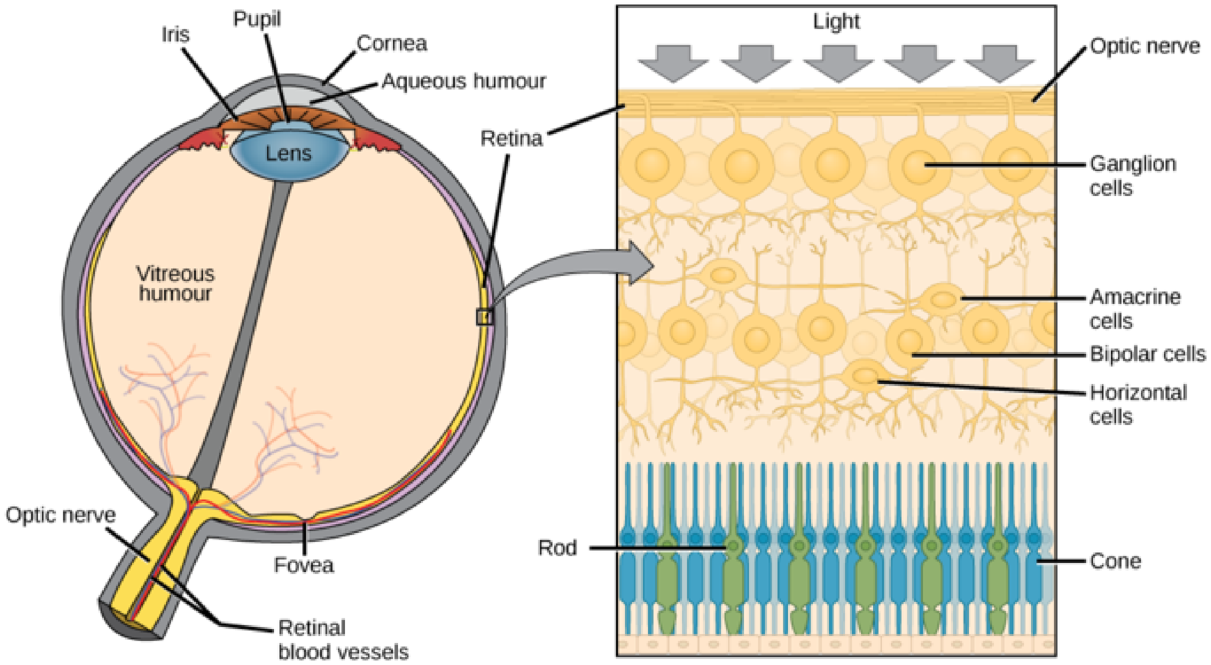
Altered gene expression alongside **environmental triggers** such as stress or use of drugs may alter the development of the brain resulting in behavioural issues and mental illness.

5.2.2 Visual function

Structure of the eye



Structure of the retina



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Sense organs are groups of receptor cells which **respond to a specific stimulus**. The eye is a sense organ which responds to **light**. Other sense organs may respond to **temperature, touch, sound and chemicals**.

Eye structure:

- **Cornea** - A clear layer which coats the iris. The cornea refracts light into the eye.
- **Iris** - The coloured section of the eye. This controls the amount of light that enters the eye by contracting and dilating the pupil.
- **Pupil** - Allows light into the eye
- **Lens** - Positioned behind the iris. The lens changes shape in order to focus the image on the retina.
- **Retina** - Contains rod and cone cells which are sensitive to light, these are also called photoreceptors. There are also many blood vessels which supply nutrients to these cells.
- **Fovea** - a section in the middle of the retina which contains a large amount of cone cells; this section provides the clearest image.
- **Optic nerve** - Each photoreceptor cell is attached to a neurone. These neurones group together to form the optic nerve, which carries the impulse to the brain.

Rods and cones:

Rods and cones are the two types of **photoreceptor cells** found in the eye:

	Rods	Cones
Shape	Rod-shaped	Cone-shaped
Function	Used for **monochromatic night vision** as they are more sensitive to low levels of light	Used for **colour vision** in bright light. There are three types of cone cells, each sensitive to a different colour (red, green and blue)
Distribution	Evenly distributed at the periphery of the retina; absent at the fovea	Concentrated at the fovea

Pupil reflex:

The **pupil** of the eye can **expand and contract** to **control the amount of light** that enters the eye. This action is carried out by two sets of muscles, **circular muscles** and **radial muscles**, which work **antagonistically**. At low light intensities, the pupil dilates to allow more light to enter the eye by contracting the **circular muscles**. At high light intensities, the pupil constricts to limit the amount of light entering the eye by the **radial muscles** contracting. This is to prevent the eye being damaged by the bright light.

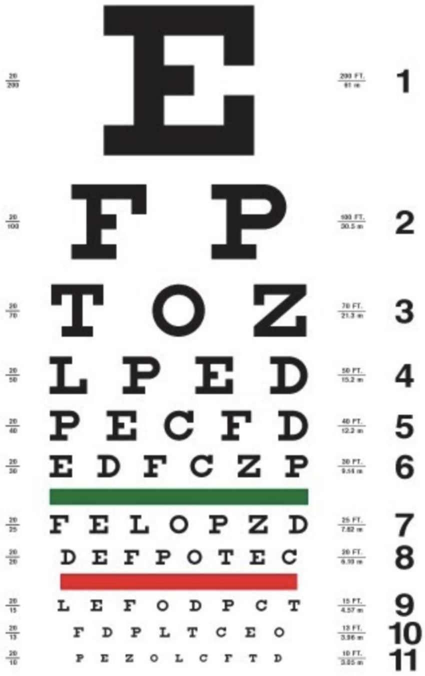
Accommodation:

The eye can **focus** on both near and far objects. This is achieved by changing the shape of the **lens,** which is controlled by the ciliary **muscles** and **suspensory ligaments**. These work **antagonistically**. The shape of the lens, as well as its curvature, is altered to change the way light is **refracted** onto the retina, focusing the image.

To focus on near objects, the ciliary muscles contract whilst the suspensory ligaments relax, making the lens **fatter and curved**. To focus on distant objects, the ciliary muscles relax whilst the suspensory ligaments contract, making the lens **thinner and less curved**.

Eye tests:

1) **Snellen's chart**



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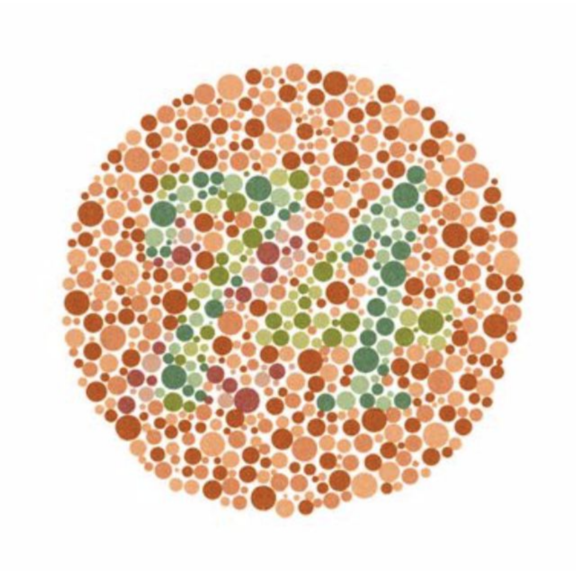
- Determines visual acuity – i.e. ability to distinguish objects at a distance.
- 20/20 vision refers to the ability to see at 20 feet what one would be expected to see at 20 feet with visual acuity that was not impaired.

2) **Colour vision – determined by Ishihara chart**



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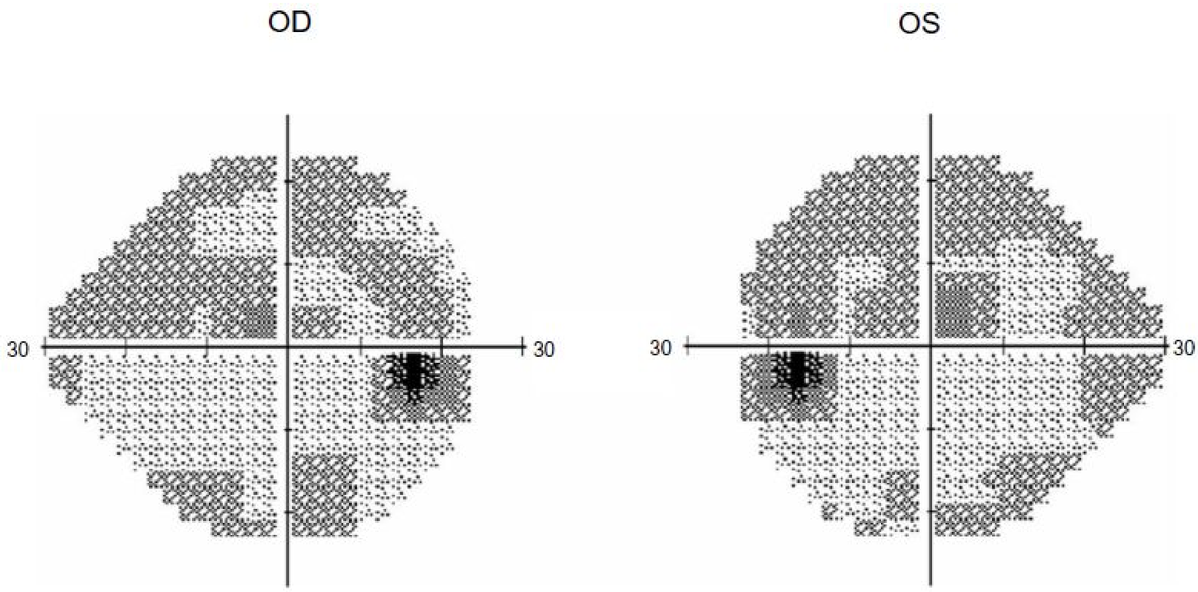
3) Field of vision

Compression of the visual tract and nerves may cause certain parts of our vision to be blurry or missing completely. This can be tested using a machine and the technique is known as perimetry.



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4) OCT [optical coherence tomography]

- Provides 3 dimensional images of the retina
- May be useful in picking up eye diseases such as optic nerve lesions and diabetic retinopathy [eye disease in diabetes].