Unit 5: Exercise, energy and coordination

Topic 8: Grey Matter

2. Describe how plants detect light using photoreceptors and how they respond to environmental cues.
How plants detect light using photoreceptors

- Phytochrome detects light. It reacts with different types of light and affects the responses of the plant
- P_R absorbs red light. P_{FR} absorbs FAR red light
- Exposure to red light changes P_R to P_{FR}. Lack of red light converts P_{FR} back to P_R
- This means that at night, P_R is converted to P_{FR}
- P_R is the most stable form but P_{FR} is the most biologically active

Response to environmental cues

- Phytochromes allow plants to respond to changes in day length
- Long day lengths mean that there is a lot of P_{FR}
- Plants germinate when there is a lot of P_{FR} ie when they have been exposed to a lot of day light
- Seeds need red light to turn their P_R into P_{FR}, the biologically active form
- As a result of this seeds found under trees with leaves blocking their light do not germinate. They wait until the leaves have fallen and decomposed to germinate. SPRING! – When they have exposure to RED LIGHT!

3 Describe the structure and function of sensory, relay and motor neurones including the role of Schwann cells and myelination.

Neurones are specialised for carrying impulses. They have: a cell body which contains the cell nucleus; mitochondria. Nissl's granules (prominent groups of rough endoplasmic reticulum) and ribosomes which are used to synthesize neurotransmitter molecules

The cell body has dendrites which connect to neighbouring nerve cells. The nerve fibre carries impulses. Axons carry impulses away from the cell body while dendrons carry impulses carry impulses towards the cell body.

*Motor neurone*s carry information from the central processing areas of the nervous system to the effector organs

Sensory neurones only carry information from the environment to the central processing areas of the nervous system

Relay neurones connect motor and sensory neurones. They are known as bipolar neurones as two fibres leave the same cell body.

Schwann cell membrane wraps itself around the nerve fibre forming a fatty layer known as the myelin sheath. This protects the nerve fibre from damage and speeds up the transmission of impulses (*saltatory conduction*). Gaps between the Schwann cells are known as nodes of ranvier.

4 Describe how a nerve impulse (action potential) is conducted along an axon including changes in membrane permeability to sodium and potassium ions and the role of the nodes of Ranvier.

Before action potential

- High concentration of K^+
- Low concentration of Na^+
- Inside more negative than outside, the axon is said to be polarised
- Potential difference is -70mV

During action potential

- The membrane becomes more permeable to sodium ions
- Sodium ion channels open and sodium ions diffuse down their concentration and electrochemical gradient
- The potential difference is reversed. -70mV to +40mV
- The inside of the cell is more positive than the outside

After action potential

- Sodium ion channels close and the sodium pump pumps out sodium ions out
- The potassium ion channels open hence the membrane is more permeable to potassium ions
- Potassium ions move out of the membrane down their concentration gradient

- The inside is more negative than the outside
- Hyperpolarisation occurs before resting potential is restored.

The role of the nodes of Ranvier

- Action potentials only occur at the nodes of ranvier as the myelin sheath prevents action potentials. This speeds up transmission
- Impulse travel by saltatory conduction. They jump from node to node

Refractory period – Recovery time of an axon after an action potential has passed. It cannot be stimulated. This ensures that impulses travel in only one direction
Absolute refractory period – The period of time following an action potential when a nerve fibre cannot be stimulated
Relative refractory period – The period of time when the axon can be restimulated but will only respond to a much stronger stimulus

5 Describe the structure and function of synapses, including the role of neurotransmitters, such as acetylcholine.

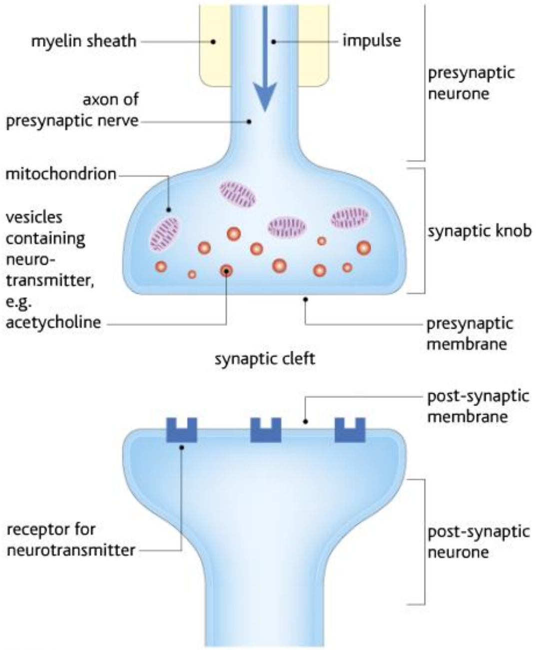


fig. 8.2.12 The structure of the synapse (based on information revealed by the electron microscope).

- Synapses pass information around the nervous system
- A synapse is the gap between two neurones
- When an impulse arrives, the presynaptic membrane becomes more permeable to calcium ions (the calcium ion channels open and calcium moves down its concentration gradient)
- Calcium ions cause neurotransmitter vesicles to move to the presynaptic membrane
- The neurotransmitter fuse with the presynaptic membrane and the neurotransmitter is released into the synaptic cleft
- The transmitter substance attach to the receptor sties on the post synaptic membrane
- An action potential is induced in the post synaptic membrane. In some neurones, an inhibitory post synaptic potential is set up making it less likely for an action potential to occur
- Any transmitter substance left in the synaptic cleft is destroyed by enzymes so that receptors can respond to a subsequent impulse.
- An example of a neurotransmitter is acetylcholine

6 Describe how the nervous systems of organisms can detect stimuli with reference to rods in the retina of mammals, the roles of rhodopsin, opsin, retinal, sodium ions, cation channels and hyperpolarisation of rod cells in forming action potentials in the optic neurones.

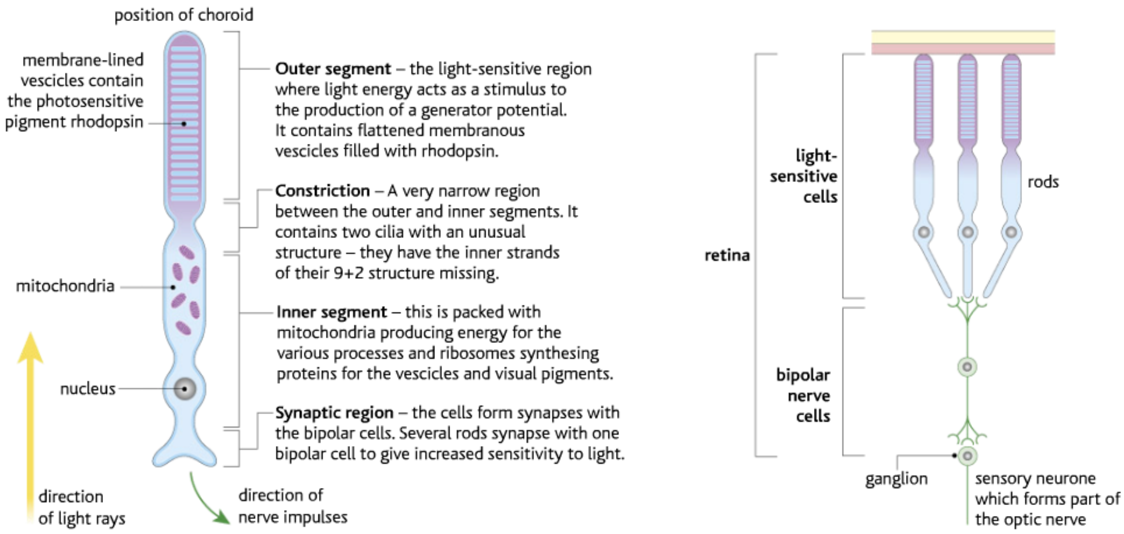


fig. 8.2.19 Rods have evolved to give great sensitivity to light, both in their structure and in their arrangement in the retina.

Rhodopsin – The visual pigment found in rods. In light it splits to opsin and retinal
Opsin – Molecule produced when rhodopsin splits in light
Retinal – Formed when rhodopsin splits in light
Hyperpolarisation - The increasing negativity of the inside of a sensory rod cell following the formation of trans-retinal and the change in permeability of the membrane to sodium ions

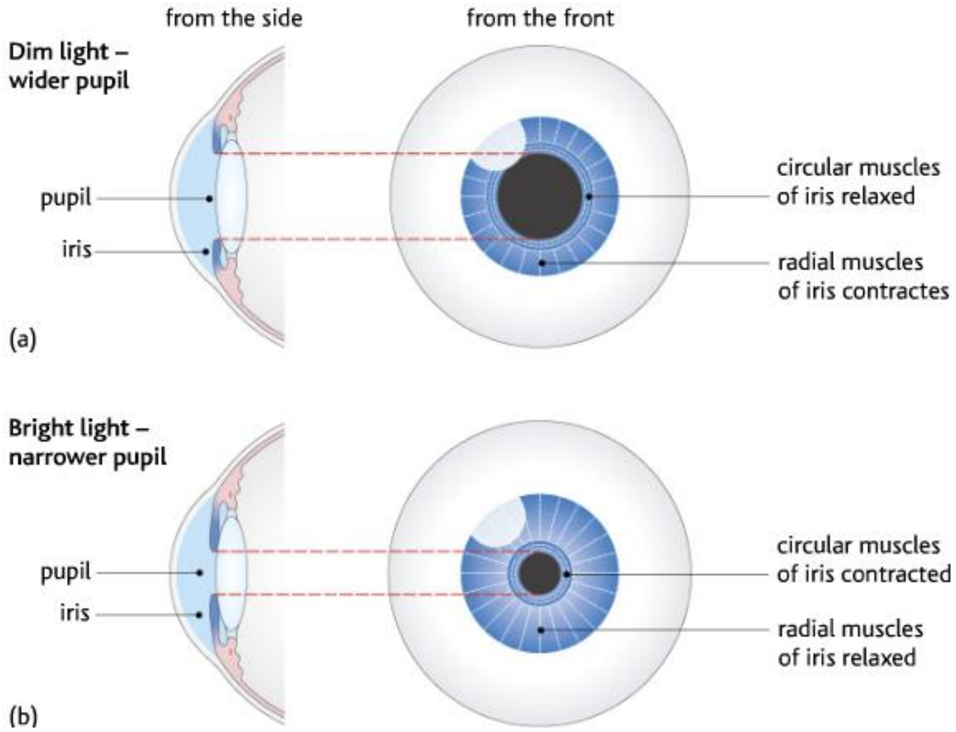
The role of the retina

- Rods provide black and white vision and are used at seeing in low light intensity or in the dark
- Rods contain rhodopsin.
- Several rods synapse with the same neurone making them extremely sensitive to low light levels and movements in the visual field. This is because small generator potentials can trigger an action potential by summation

How do rods work

- When light hits a rod, rhodopsin is bleached
- Cis-retinal changes to trans-retinal, this changes the shape of retinal, putting a strain on the bonding between opsin and retinal. As a result, rhodopsin splits into opsin and retinal.
- Unlike most neurones, rods are permeable to sodium ions. As sodium moves into the membrane, the sodium pump actively removes the sodium ions
- Bleaching causes the rod cell membrane to become less permeable to sodium (the sodium ion channels shut)
- The sodium pump continues to pump sodium out of the membrane. This causes the membrane to become hyperpolarised. The hyperpolarisation is the generator potential.
- The size of the generator depends on how much rhodopsin is bleached.
- If the generator potential is large enough or several generator potential join by summation to become large enough, an action potential is set up in the bipolar cell which passes across the synapse to cause an action potential in the sensory neurone.
- Impulse sent along optic nerve to the brain

7 Explain how the nervous systems of organisms can cause effectors to respond as exemplified by pupil dilation and contraction.



Reflexes are the basis of most nervous systems. They are fixed, fast and unconscious

The Iris as an effector

- The iris is a muscular diaphragm with a hole, the pupil, in the middle
- The amount of light entering the eye is controlled by the size of the pupil
- The iris has both radial and circular muscles that work antagonistically

Bright Light

- Light falling on rods causes impulses to travel along neurones
- Brighter light means the frequency of action potentials increases.
- This is detected by a control centre in the midbrain
- Nerve impulse synapses with the parasympathetic cranial nerve.
- The muscles in the iris are stimulated
- The circular muscle contracts and the radial muscles relax
- Pupils reduced to a narrow aperture, reducing the amount of light entering the eye
- This prevents damage to rods and cones by overstimulation

Dim Light

- Light falling on cones causes impulses to travel along neurones
- Dim light means the frequency of action potentials decrease
- This is detected by a control centre in the midbrain
- Nerve impulses synapse with the sympathetic cranial nerve
- The muscles in the iris are stimulated
- The circular muscles relax and the radial muscles contract
- Pupils are wider, increasing the amount of light entering the eye
- This allows as much light as possible to fall on the rods and cones to maximise what you can see

Emotional cues

- When stress hormone adrenaline is released, the pupils widen to ensure you can use all the light available
- Pupils dilate when you see someone you are physically attracted to
- Pupils constrict when you see someone you don't find attractive

8 Compare mechanisms of coordination in plants and animals, ie nervous and hormonal, including the role of IAA in phototropism (details of individual mammalian hormones are not required).

- Coordination in plant is brought about by plant hormones

- Some aspects of growth and sexual maturity as well as responses to stress and control of blood sugar levels are controlled by hormones in mammals

Hormonal Control

- Relatively slow but long lasting
- They are carried around plants and mammals in mass transport systems. Carried in the plasma for mammals and carried in the phloem for plants
- Hormones are picked up by receptors on the cell membrane of the target molecules
- Hormonal control is often linked to changes involved with growth. It allows for long-term responses to environmental cues

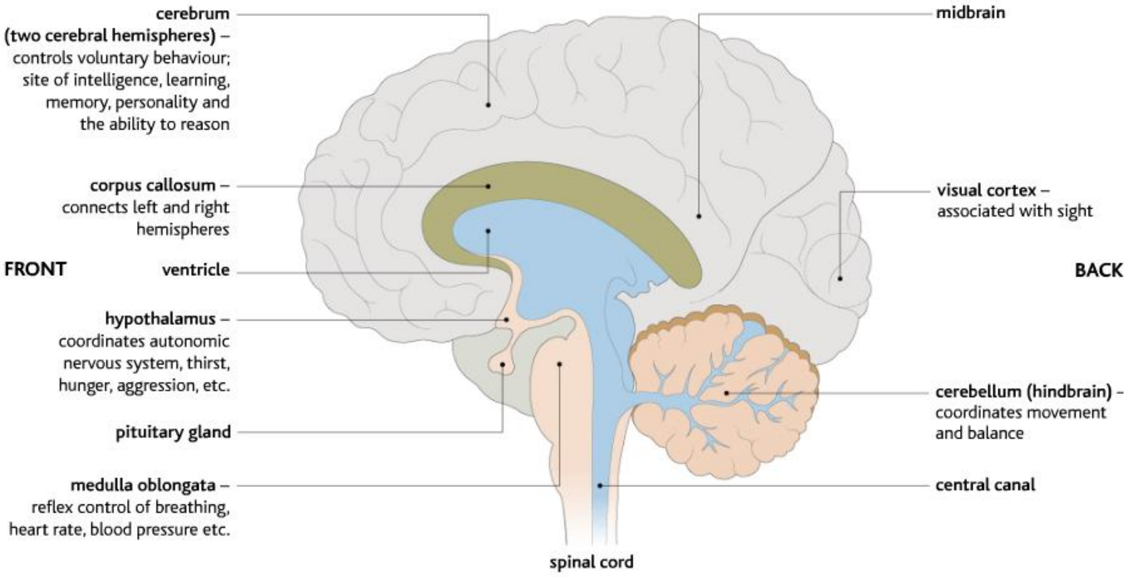
Nervous Control

- Very rapid so ideal for internal communications in organisms that move their entire body

Role of IAA in plants

- It is an auxin
- Auxins are plant growth hormones
- See spec point 2

9 Locate and state the functions of the regions of the human brain's cerebral hemispheres (ability to see, think, learn and feel emotions), hypothalamus (thermoregulate), cerebellum (coordinate movement) and medulla oblongata (control the heartbeat).



10 Describe the use of magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI) and computed tomography (CT) scans in medical diagnosis and investigating brain structure and function.

- Help to investigate the development of the brain and link structures to function
- Help to understand the progress of brain diseases and how they affect people
- X-rays enable us to take images of bones but cannot produce images of soft tissue. CT, MRI and fMRI

Computerised Tomography (CT Scans)

- Thousands of tiny X-ray beams are passed through the area to be observed
- The strength of the beam is reduced as it passes through tissue. Denser tissue reduces the strength of the beam more.
- The X-rays that make it through are detected and measured
- The data is put into a computer to produce a cross-sectional image of a thin slice of the body
- Occasionally, special dyes are injected into the blood to make areas X-ray opaque so they show up more clearly
- Positives: able to identify major structures in the brain; can identify bleeding in the brain
- Downside: can't pick up fine structural details; Images are frozen in time so cannot show how different areas of the brain change with different activities

Magnetic Resonance Imaging (MRI)

- Uses magnetic fields and radio waves
- Hydrogen atoms are imaged as they have a strong MRI signal
- The signals produced are used to produce an image by a computer.

- Different tissues respond differently to the magnetic field due to the amount of water in the structure.
- Thin slices are imaged to produce 2D images. However, these can be put together to form 3D images
- Positives: Reduces risk of damage from X-rays; produces detailed images; can be used to diagnoses brain injuries, strokes, tumours and infections of the brain or spine; enables doctors and scientists to make links between the structures in the brains and patterns of behaviour seen in their patients
- Downside: Doesn't show how the brain works; noisy so can be distressing for the patient

Functional Magnetic Resonance Imaging (fMRI)

- Monitors the uptake of oxygen in different areas of the brain while people undertake different tasks
- Deoxyhaemoglobin absorbs radio waves and re emits it. Oxyhaemoglobin does not.
- An active area of the brain contains a lot of Oxyhaemoglobin so less radio waves are absorbed. Therefore, an active area of the brain absorbs and emits less energy than a non active part
- Positives: gives an extremely spatially accurate image of the brain
- Downside: Noisy so can be stressful for the patient; patient's head has to be still, movement reduces the accuracy of the image; some scientists argue that blood flow to different areas due to patients looking at different stimuli is correlation not causation

11 Discuss whether there exists a critical 'window' within which humans must be exposed to particular stimuli if they are to develop their visual capacities to the full.

- The way in which the brain develops is controlled by genes and environmental stimuli
- Critical windows are periods of time in which vital neural connections are made in the brain in response to specific stimuli. If the stimulus is not received in that period of time, that area of the brain will not develop normally.
- A study conducted by injecting newborn ferrets with radioactive tracers show that the arrangement of cells in the eyes in columns is already present in the visual cortex at birth. It is not as a result of nature.
- A study conducted on newborn monkeys . The monkeys were taken out 8 days before the end of their normal gestation period. The monkeys visual cortex did not develop completely. This shows that there could be a critical window of time.

12 Describe the role animal models have played in developing explanations of human brain development and function, including Hubel and Wiesel's experiments with monkeys and kittens.

- There is a critical window for the development of the mature visual cortex
- The eyes of new-born kittens and monkeys were sutured. The age at which the animals were deprived of vision and the length of time the eye remained closed was varied
- One eye of a kitten was sutured before its eyes opened. The open eye developed normally, however, the kittens were blind in the closed eye; very few cells in the closed eye were firing
- One eye of a four month old kitten that could see normally was sutured. There was no effect on the vision of the sutured eye
- Closing the eye of a kitten for a short period during the critical period for visual development has as much effect as closing the eye from birth.
- Similar results were achieved when monkeys were used.

How the visual cortex develops

- Columns of the visual cortex are present at birth
- At birth, there is a lot of overlap in the dendrites and synapse from the axons in different columns.
- As a result of visual experience, an adult has considerably less overlap.
- If an axon is not stimulated, it is weakened and destroyed. This occurs all over the nervous system to reduce the amount of unwanted axons ensuring that messages are carried efficiently to exactly where they are needed.
- When one eye is deprived of light, axons associated with it weaken and die. The other eye dominates the area of the cortex where they overlap.

13 Consider the methods used to compare the contributions of nature and nurture to brain development, including evidence from the abilities of newborn babies, animal experiments, studies of individuals with damaged brain areas, twin studies and cross-cultural studies.

Individuals with damaged brains

- Evidence shows that when an area of the brain is damaged, new connections can be made bypassing the damged area. A different part of the brain takes over the job