CAIE Biology A-level

Topic 15: Control and coordination

Notes

Neuron structure

The nerve cells called **neurones** play an **important role in coordinating communication** within the nervous system. The **stimuli** is first detected by **sensory receptor cells** which is then transmitted to the sensory neurone.

The **structure of neurones is similar**, as they all have a **cell body composed of the nucleus** as well as **organelles such as mitochondria within the cytoplasm**. Apart from the essential components, they also contain extensions called **dendrites** involved in conducting impulses towards the cell body, as well as **axons** which conduct them in the opposite direction, that is away from the cell body.

There are three types of neurones, **sensory, motor and relay** with different functions which differ by the position of the cell body within the neurone.

- **Motor neurones** are involved in transmitting electrical signals from the central nervous system to muscles and glands in the body.
- **Sensory neurones** transmit impulses from receptors to the central nervous system.
- **Relay neurones** are located within the central nervous system and transmit the electrical impulses from sensory neurones to motor neurones.

The structure of neurones, that is the length of axons as well as the **polarised** nature of the neurone membrane in the resting state where the **outside of the membrane is positively charged** and the **inside is negatively charged** enables the neurones to carry electrical impulses called **action potentials**.

The speed at which the electrical potential is carried can be increased with the help of **myelin sheath** which serves as an insulator of axons and dendrons produced by **Schwann cells**. The mechanism by which the speed is increased is known as **saltatory conduction** where the action potential jumps between gaps in the myelin sheath called **nodes of Ranvier.**

Nerve impulse conduction

Nerve cells are **polarised in their resting state**. This occurs as a result of **imbalance between sodium ions and potassium ions**, thus giving the inside of the nerve cell a negative charge in comparison to the external environment. As a result of the polarisation, there is a difference in the voltage across the neurone membrane, with a value of -70mV known as the **resting potential**.

This resting potential is generated as well as maintained with the help of **sodium-potassium pump** which **moves sodium ions out of the neurone** thus creating an electrochemical

gradient as the **concentration of sodium ions is higher outside the cell** because the **membrane is not permeable to sodium ions**. The sodium-potassium pump is also involved in **transporting the potassium ions into the neurone**. However, the **potassium ions diffuse back out due to the presence of potassium ion channels**. As a result of this, the **outside of the cell is positively charged** due to the imbalance of positively charged ions.

Upon stimulation, the neurone cell membrane becomes **depolarised**. This occurs as following: firstly, the excitation of neurone cell triggered by stimulus **causes the sodium ion channels to open, making it more permeable to sodium ions** which subsequently **diffuse into the neurone** down the electrochemical gradient, as a result **making the inside less negative**. Upon reaching the threshold of **-55mV,** even **more sodium channels open** eventually giving a potential difference of **+30mV** which is the end of the depolarisation and start of **repolarisation**. This is achieved as a result of **sodium ion channels closing and potassium ion channels opening**. The **potassium ions diffuse out of the neurone** down the concentration gradient and eventually **restore the resting potential**. However, as the **closing of potassium ion channels is slightly delayed**, this leads to **hyperpolarisation** i.e. when the potential difference becomes greater than the resting potential. The resting potential is then achieved with the help of sodium-potassium pump which returns the potential difference to the value of -70mV.
The action potential travels along the neurone as a **wave of depolarisation** where the **sodium ions move to the adjacent resting region.** Here they **trigger a change in potential difference,** thus **stimulating another action potential**.

Afterwards, there is a short period during which the neurone membrane cannot be excited as the sodium channels enter the recovery stage. This period is known as the **refractory period** and serves an important role in ensuring that the **action potentials can only pass in one direction as discrete signals**. It also **limits the number of impulses** that can be sent.

Synapses

Synapses are junctions between two neurones. Upon the arrival of an action potential, the **presynaptic membrane** depolarises therefore **causing the calcium channels to open** which subsequently **allow calcium ions to enter the neurone**. The presence of calcium ions in the neurone causes **the fusion of synaptic vesicles** filled with a particular neurotransmitter such as **acetylcholine** to **fuse with the presynaptic membrane** thus causing the release of neurotransmitter into the **synaptic cleft** (the gap between the two neurones). Afterwards, the **neurotransmitter binds to the receptors** located on the postsynaptic membrane therefore **stimulating the opening of cation channels** which enable sodium ions to enter the neurone. As a result of that, the membrane depolarises therefore **triggering another action potential**. This process only occurs if the neurotransmitter originates from an **excitatory neurone**. In the case of **inhibitory neurones,** chloride ions open, thus causing hyperpolarisation of the post-synaptic membrane therefore triggering a new action potential becomes more difficult.

This sequence of events is controlled with the help of digestive enzymes in the synaptic cleft which serve to break down the neurotransmitter to prevent overstimulation of the post-synaptic membrane. Following the breakdown of the neurotransmitter, it is **taken up by the pre-synaptic membrane and resynthesized in vesicles**. Apart from this, the **presence of receptors on one side of the synapse only**, that is the post-synaptic side serves to ensure that the **action potential can only travel in one direction only.**

Muscles

Key words:

- **Tendons** – non-elastic tissue which connects muscles to bones
- **Ligaments** – elastic tissue that joins bones together and determines the amount of movement possible at a joint
- **Joints** – the area where two bones are attached for the purpose of permitting body parts to move, they're made of fibrous connective tissue and cartilage
- **Skeletal muscles-** muscles attached to bones, they are arranged in antagonistic pairs
- **Antagonistic muscle pairs-** pairs of muscles which pull in opposite directions – as one muscle contracts, the other relaxes**. Flexors and extensors** are an antagonistic muscle pair such as triceps and biceps. When the triceps relaxes, the biceps contracts to lift the arm
- **Neuromuscular junction** - the junction between a motor neurone and a skeletal muscle fibre

Striated muscle, also known as **skeletal muscle**, makes up most of the muscles in the body and is used for voluntary movement. It is made up of large bundles of long muscle fibres. They contain **myofibrils**: long, cylindrical organelles that are specialised for muscle contraction, made of **actin and myosin**. The cells also contain many nuclei and mitochondria to provide energy for movement.

Myofibril contraction:

1. An impulse arrives as a neuromuscular junction, **Ca2+ is released** from the **sarcoplasmic reticulum**.
2. Ca2+ binds to troponin, causing a **shape change**. Consequently, the tropomyosin moves away from the actin, **uncovering binding sites**
3. Myosin binds to the uncovered actin binding sites, forming an **actomyosin cross bridge.**
4. ADP and inorganic phosphate ions are released, causing the **power stroke**
5. After this, ATP binds, causing myosin to unbind from the actin
6. ATP breaks town to ADP and inorganic phosphate to return the myosin to its original position
7. Ca2+ ions are reabsorbed, troponin moves back to its original shape and tropomyosin re-covers the binding sites.

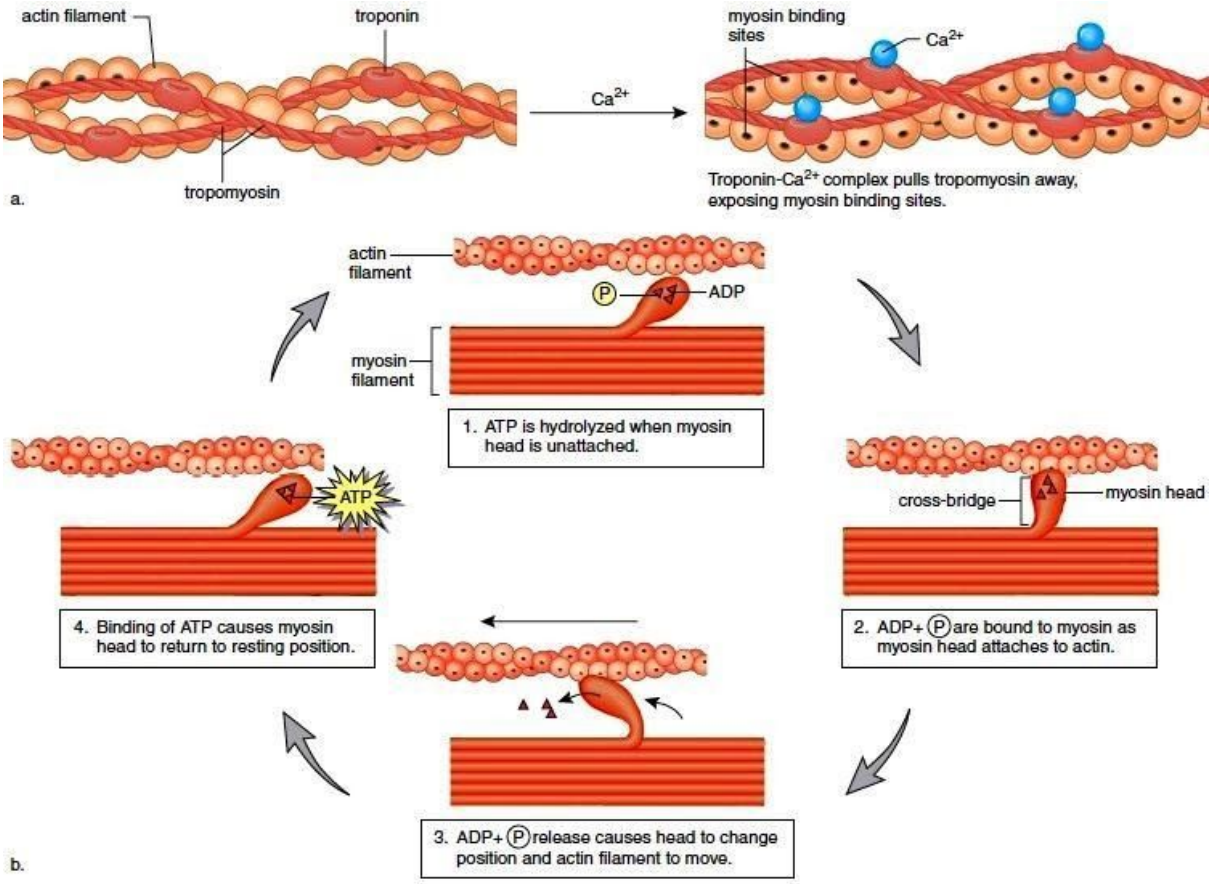

*Figure SEQ Figure * ARABIC 1 Medical Library Online*

Role of ATP in myofibril contraction:

- Allows **actomyosin cross bridge to detach** and is hydrolysed so that the myosin can return to its original position. (Allows muscle to relax).
- Allows **reabsorption of Calcium ions** via active transport.

Hormones and human menstrual cycle

Production of eggs and preparation for fertilisation occurs during the menstrual cycle in the uterus and ovaries of females. Four main hormones are involved in the cycle; **progesterone, oestrogen, follicle stimulating hormone and luteinising hormone.**

The roles of the hormones are as following:

- **FSH** is involved in stimulation the development of eggs and release of oestrogen
- **LH** stimulates egg release, oestrogen and progesterone production

- **Oestrogen** stimulates uterine lining growth and egg release, inhibits FSH and LH after ovulation
- **Progesterone** maintains the lining of the uterus, involved in inhibiting LH after ovulation

Oral contraceptives contain oestrogen or progesterone which inhibit the production of FSH, thus preventing the egg development.

The endocrine system

Consists of endocrine gland which releases hormones directly into the bloodstream. Some hormones involved in the endocrine system are:

- **ADH (antidiuretic hormone)**
  - Involved in **osmoregulation** which is the maintenance of the water potential balance in the blood.
  - When the bloods water content is low, ADH is released by the posterior pituitary gland
  - Increases the DCT and collecting duct wall's permeability to water
  - Increases reabsorption of water from the tubules into the blood

- **Glucagon**
  - Involved in the control of **blood glucose concentration**
  - When glucose concentration is too low, glucagon is released from the alpha cells of the islets of langerhans
  - Stimulates hepatocytes to convert glycogen to glucose which diffuses out of hepatocytes into the blood

- **Insulin**
  - Involved in the control of **blood glucose concentration**
  - When glucose concentration is too high, insulin is released from the beta cells of the islets of langerhans
  - Stimulates hepatocytes to convert glucose into glycogen which is stored in the muscle until needed for respiration

Control and coordination in plants

Plant growth responses can also be triggered by **plant growth regulators**. Examples include **auxins** which promote cell elongation, **gibberellins** which promote seed germination and stem growth, **abscisic acid** which inhibits seeds germination and causes closing of stomata and **ethane** which is a gas that promotes ripening of fruit. The height of plants is controlled by whether the active form of gibberellin is present, which is determined by the plants genes: if the dominant allele (Le) is present, gibberellin is active and the plant grows tall, if the recessive allele (le) is homologously present, a non-functioning gibberellin enzyme is coded for, thus the plant remains short.

Auxins cause cell elongation via the transport of hydrogen ions into the cell walls, which as a result lowers the pH of the walls, which is required for **expansins**. Expansins are a special type of enzyme **involved in loosening the cellulose**, this makes **cell walls stretch to accommodate more water**- thus enabling the expansion and growth of cells.

When the shoot is illuminated from all sides, the auxins are distributed evenly and move down the shoot tip thus causing elongation of cells across the zone of elongation. Whereas **if the shoot is only illuminated from one side**, the auxins move towards the shaded part of the shoot thus causing elongation of the shaded side only which results in bending of the shoot towards the light.

Another example of control and coordination in plants is the rapid response of **Venus fly trap** to stimulation of hairs on the lobes of modified leaves. Closure of the trap is achieved through stimulation of the hairs which stimulate the release of calcium ions and production of an action potential. Closing of the trap only occurs if several hairs are stimulated, and the trap seals when further stimulation of hairs occurs. When the trap is sealed, digestive enzymes are released to break down the insect.