OCR (B) Biology GCSE

Topic B5: The human body - staying alive

Notes

(Paragraphs in **bold** are higher tier only)

How do substances get into, out of and around our bodies?

Hundreds of different substances are constantly transported around the body. These substances include **gases** and **nutrient molecules** that are being transported to certain organs or cells in order for **metabolic reactions** to take place, as well as **waste materials** which must be **excreted** from the body. The movement of molecules in and out of cells is controlled by **partially permeable membranes**, that regulate which molecules can pass across them. Substances move into and out of cells and blood vessels via **diffusion, osmosis and active transport**.

The **cardiac system**, made up of the **heart and a network of blood vessels**, is the main transport system of the body and carries gases, nutrient molecules, hormones and other substances to and from cells.

How the heart functions

1. Deoxygenated blood enters the heart through the **vena cava** (vein) into the **right atrium**.
2. The right atrium contracts and blood moves through the **tricuspid valve** to the right ventricle.
3. The ventricle contracts and blood exits the heart through the **semilunar valve** to the **lungs** via the **pulmonary artery**.
4. Blood becomes oxygenated in the lungs and then returns to the heart via the **pulmonary vein**, entering the **left atrium**. The left and right sides of the heart are separated by the **septum,** which makes sure that oxygenated and deoxygenated blood remain separate.
5. The left atrium contracts and blood moves through the **bicuspid valve** into the left ventricle.
6. The left ventricle contracts and oxygenated blood exits the heart past the **semilunar valve** through the **aorta** (artery) and travels around the body, becoming deoxygenated as oxygen diffuses into tissues. The wall of the left ventricle is much **thicker** than the right side, as it must be able to pump blood at **high pressure** around the entire body, rather than just to the lungs. The walls of both ventricles are thicker than the atria walls.

The bicuspid and tricuspid valves are known as the **atrioventricular valves** as they prevent backflow between the ventricles and atria. Valves are present in the heart and veins to **prevent backflow** of blood. They are **not present in arteries** as the pressure is high enough that backflow does not occur.

Types of blood vessel

There are three main types of blood vessel: **capillaries, arteries and veins**. Usually, **deoxygenated blood travels in veins towards the heart** and **oxygenated blood travels in arteries away from the heart**. The only exception to this is the pulmonary artery, which carries deoxygenated blood from the heart to the lungs, and the pulmonary vein which carries oxygenated blood from the lungs to the heart. Capillaries are the **smallest** type of blood vessel and hence are **where exchange usually takes place**.

Blood vessels are adapted to carry out different functions:

- Arteries have **thick muscle and elastic layers** which help the vessel to **maintain and control high blood pressure**, and a **thick wall** to **prevent bursting**.
- Veins have a **thin muscle and elastic layer**, as well as a **thin wall**. This is because the blood is at **low pressure**, so blood flow does not need to be controlled and there is less risk of bursting. They also contain **valves** which **prevent backflow** of blood.

- Capillaries are adapted for **exchange** as oppose to transport. This means that they must have a **large surface area**, a **thin diameter and lumen** to **decrease diffusion distance**, and a **slower blood flow** to allow time for exchange to take place.

Transport of substances in the blood

Oxygen diffuses into capillaries at the **alveoli** in the **lungs**, where it binds to **haemoglobin** in the blood. It is then transported to cells where it can be used in **respiration**. **Carbon dioxide** is produced as a waste product. This exits the cells via **diffusion** and is carried back to the lungs where it is excreted from the body.

Nutrient molecules diffuse into capillaries in the **small intestine** at specialised exchange surfaces called **villi**, which are hair-like projections from the intestine wall. These nutrients have been broken down during **digestion** which makes them small enough to pass through the partially permeable membrane. These molecules are then transported in the blood to cells where they are used in **metabolic reactions**. Substances which do not pass through the membrane are excreted from the body.

Waste products from tissues diffuse back out of cells into the blood in order to be **excreted** from the body to prevent a build-up of potentially harmful substances. An example of a waste product is **urea**, which is formed in the **liver** as a result of an **excess of amino acids**. Urea is transported in the blood from the liver to the **kidney**, where it is **filtered** from the blood by the kidney and **excreted from the body as urine**.

Adaptations of exchange surfaces

Specialised exchange surfaces are needed to allow substances to be transported through the body efficiently. They are adapted by:

- Having a **short diffusion distance** - cells acting as exchange surfaces are very thin to reduce the distance that substances must travel, making diffusion faster.
- Having a **large surface area** - allows more molecules to move across at once. For example, the alveoli in the lungs have a huge surface area of 80-100 square metres.
- Having a **large concentration gradient**- molecules will diffuse from an area of high concentration to an area of low concentration more quickly if there is a large difference in the concentrations. A low concentration is maintained by blood vessels carrying the diffused molecules away from the exchange site (for example capillaries carry oxygen away from alveoli in the lungs), or the molecule is used up in a cellular reaction.
- Being **moist** - this allows gases to dissolve before diffusing across the membrane.

How does the nervous system help us respond to changes?

Both controlled movement and autonomic reflexes are carried out by the nervous system. The nervous system controls movement by sending electrical signals known as nerve impulses along a network of specialised nerve cells called neurones. This allows coordinated movement and a constant internal environment to be maintained (homeostasis), which improves the chances of survival for an organism.

The nervous system consists of two main sections: the central nervous system (CNS) and the peripheral nervous system. The CNS is made up of the brain and spinal cord, whereas the peripheral nervous system contains motor and sensory neurones, which carry impulses to and from the CNS.

Types of neurone:

- Sensory - carries impulses from a receptor to the spinal cord and brain.
- Relay (connector) - carries impulses between different parts of the central nervous system.
- Motor (effector) - carries nervous impulses from the central nervous system to the effector, e.g. a muscle.

Synapses

Where two neurones meet is called a synapse. The synapse forms a gap called a synaptic cleft between the presynaptic neurone and the postsynaptic neurone. When an impulse arrives at the presynaptic neurone, vesicles in the neurone fuse with the membrane, releasing a neurotransmitter into the synaptic cleft. The neurotransmitter diffuses across the synapse, binding to receptors on the postsynaptic neurone. This triggers a nervous impulse in the postsynaptic neurone, thus the impulse can continue.

Synapses ensure unidirectionality of nervous impulses, as the vesicles containing the neurotransmitter are only present in the presynaptic neurone, whilst the receptors are only present in the postsynaptic neurone, thus the impulse cannot travel backwards.

Nerve cell adaptations

The function of a nerve cell is to pick up an impulse from one neurone and pass this to the next neurone. As nervous impulses must occur almost instantaneously, nerve cells must be adapted to carry electrical impulses quickly and efficiently:

- The axon has a myelin sheath, made of Schwann cells, surrounding it. This provides electrical insulation when the nerve impulse passes down the axon which speeds up the impulse.
- The axon is long to carry the impulse over long distances quickly. Passing an impulse between two neurones across a synapse slows the impulse down.
- Nerve cells contain neurotransmitter substances which they secrete at synapses to allow the impulse to continue in the next neurone.
- The nerve cell has dendrites which pick up electrical impulses from other neurones.
- Receptors are specialised nerve cells which respond to one of a number of different stimuli: neurones in the skin react to pressure (touch), neurones in the eyes react to light, and neurones in the ears react to sound.

Reflexes

Some movement is **involuntary**; organisms have adapted to carry out automatic reflexes when in danger in order to quickly remove themselves from a hazard such as fire or sharp objects. As these reactions must occur almost instantly to protect the organism, the nervous impulse **does not travel to the brain**. **Voluntary** impulses are controlled by the brain.

The reflex arc:

1. A **stimulus**, such as heat from a flame, is detected by **receptors**.
2. The receptor sends an impulse down the **sensory neurone** to the **spinal cord**.
3. The **relay neurone** in the CNS passes the impulse to the **motor neurone**.
4. The impulse travels along the motor neurone to an **effector** (e.g. a muscle), which reacts to remove the organism from the danger.

The brain structure (biology only)

- **Cerebral cortex** - responsible for processing nervous signals, thought, problem solving, language and a number of other functions.
- **Brain stem** - connects the brain to the spinal cord and controls the communication between the brain and body. It also regulates involuntary actions such as heart and breathing rates.
- **Cerebellum** - located at the back of the brain behind the brain stem, the cerebellum is responsible for coordinated movement.

Research into the structure and functions of the brain could have a huge impact on the **ability to cure diseases in the ageing population**, such as Alzheimer's and Parkinson's disease. In many of these diseases, **nerve cells in the cerebral cortex begin to die**, which results in a **decrease in functionality**. Knowledge of which areas of the brain control which functions would allow the direct cause of these diseases to be known, and thus a cure to be developed.

Studying the brain is extremely difficult, however. This is because there are billions of neurones, and in order to learn the function of many of these the brain must still be working, meaning that the patient must be alive. There are also ethical issues with studying the brain of patients with brain damage, as they may not be able to give informed consent. In addition, it may be difficult to theorise the cause of a certain problem as studies will only be carried out after the damage has occurred, so it cannot be compared to their healthy brain. Brain damage also rarely causes a singular problem; thus, it may be difficult to match which problem is caused by which damaged neurones.

Some functions can be mapped using non-invasive methods, such as functional magnetic resonance imaging (fMRI), PET scans and electrical stimulation. This means that the brains of healthy patients can be compared to those with various diseases to see the differences and thus theorise the cause. These methods are limited, however, as they are expensive, have poor temporal and spacial resolution, and some scanning methods may cause tissue damage.

How do hormones control responses in the human body?

The endocrine system

The endocrine system **produces and secretes hormones**. It is made up of a network of hormone-secreting glands and helps to **control growth, metabolism and homeostasis**, among other functions, and enables the body to react to both **internal and external stimuli**. This system provides **slower, longer-lasting responses** than the nervous system.

Hormones are molecules that travel in the blood and are used for **signalling** in the body. They are **produced in glands** such as the pituitary and adrenal glands, before being **excreted into the blood**, where they travel to **target organs.** When they reach a target organ, they bind to receptors on the cell surfaces called effectors, which stimulates a response from within the cell.

Most hormones are regulated by negative feedback systems. This is where a response is only carried out if a certain variable (e.g. temperature or blood glucose level) moves outside of an optimum range; corrective mechanisms then work to correct the change to move the variable back to the optimum. Examples of negative feedback include:

- **Thyroxine**
  Thyroxine is a hormone secreted by the thyroid. It travels in the blood to target organs, such as the liver and kidney, where it is used as a catalyst to regulate a variety of functions, including metabolic rate, growth and development, and digestion. The release of this hormone is controlled by a negative feedback loop: if the levels of thyroxine in the blood become too high, it is detected by receptors in the hypothalamus which trigger another hormone to be released by the pituitary gland. This travels to the thyroid and prevents the release of thyroxine.

- **Adrenaline**
  The hormone adrenaline is released from the adrenal glands, located at the top of the kidneys. Adrenaline is secreted during the 'fight or flight' response, and when stressed or excited, and leads to an increase in pulse rate and widened pupils. It also causes glycogen to be converted to glucose in cells to be used in respiration for energy. Heart rate increases to provide more oxygen for this. When the body is under stress, the hypothalamus detects that there is a low level of adrenaline in the blood. This causes a hormone to be released which triggers adrenaline release from the adrenal gland.

Why do we need to maintain a constant internal environment?

Homeostasis is the maintenance of a constant internal environment in organisms, despite external changes. This allows the environment to be at an optimum for cells to function. Internal conditions must be maintained between set limits and if these limits are exceeded, negative feedback mechanisms work to correct the change and restore the internal environment to the optimum. These mechanisms include hormones, nerves, receptors and effectors.

Regulating temperature (biology only)

It is important to maintain a constant temperature of 37°C in humans as this is the optimum temperature for enzyme reactions. If the temperature was lower, the rate of reaction would decrease so reactions would take too long to occur. If it was too high, the enzymes may denature and prevent reactions from occurring. **The body's temperature is regulated by the hypothalamus in the brain, which receives information about internal and external temperature from thermoreceptors in the skin and hypothalamus. If the temperature moves away from the optimum, a response is triggered to return the temperature to the optimum. This is an example of negative feedback.**

Reactions to a low internal temperature:

- Shivering - muscles contract to produce heat.
- Vasoconstriction - blood vessels constrict to reduce surface area and move away from the surface of the skin to reduce heat loss.
- Hair erection - hairs stand on end to trap warm air. This reduces heat loss from the skin.

Reactions to a high internal temperature:

- Sweating- sweat evaporates from the skin, reducing the surface temperature.
- Vasodilation - blood vessels dilate, causing more heat loss to the environment.

Regulation of water balance in the blood (biology only)

Water balance is regulated by the kidney. The kidneys filter water and urea from the blood into kidney tubules. Here, water is reabsorbed into the blood.

The amount of water that is reabsorbed is controlled by a hormone called ADH. Osmoreceptors in the hypothalamus detect changes in the amount of water in the blood. If there is too little water in the blood, a nervous impulse is sent to the pituitary gland in the brain, which triggers the release of ADH into the blood. ADH travels to the kidney where it controls the permeability of cells to water, meaning that it controls how much water is reabsorbed from the kidney tubules. A high amount of ADH will make the cells more permeable so more water is reabsorbed into the blood. When the blood returns to its optimum concentration, ADH stops being released and the cells become less permeable again. This is another example of negative feedback, as ADH is only released when the concentration deviates from the optimum range.

It is important to maintain water concentration in the blood to prevent unwanted osmosis. If there is too much water in the blood, water will move via osmosis into cells, causing them to burst. If there is too little, water will move out of cells, causing them to shrink. This will result in cell death and tissue damage, so it is important that water balance is maintained.

What role do hormones play in human reproduction?

Hormones and the menstrual cycle

A variety of interacting hormones are used to regulate the menstrual cycle and ovulation in women. The menstrual cycle happens approximately every **28 days**. During each cycle, an **egg cell is released** from the ovaries. The **uterus wall thickens** by filling with blood capillaries in preparation for a pregnancy, which would occur if the egg is fertilised. If this egg is not fertilised, the egg dies and **menstruation** occurs, where the dead egg cell and old uterus lining is expelled from the body in a **period**.

The menstrual cycle is regulated by four interacting hormones:

- FSH **- Follicle stimulating hormone triggers the development of an egg cell in the ovary, and also stimulates oestrogen production. Oestrogen is produced in the pituitary gland.**
- LH **- Luteinising hormone triggers an egg to be released in ovulation, as well as stimulating progesterone production in the ovaries.**
- Progesterone **- Progesterone is responsible for maintaining the thick uterus lining in the cycle and during pregnancy. When progesterone levels drop, the uterus lining breaks down and menstruation occurs.**
- Oestrogen **- Helps to repair and thicken the uterus lining after menstruation. Oestrogen inhibits FSH. When oestrogen levels increase, LH is released which causes ovulation.**

The menstrual cycle can be controlled artificially by taking these hormones. This can be used to **prevent pregnancy** by **inhibiting ovulation** so that no egg is released. These hormones are usually taken as an oral pill containing **oestrogen and progesterone**. Although these pills prevent pregnancy, they **do not prevent the spread of sexual diseases**.

Hormones can also be used to promote pregnancy in some women who are infertile. There are a variety of different hormone medications which can be taken to treat different causes of infertility. For example, some stimulate ovulation or facilitate the development of extra eggs, and others work to prevent premature ovulation. These treatments are usually taken as a pill or injected. Not all causes of infertility can be treated using hormones, however.

What can happen when organs and control systems stop working?

Blood sugar level

Blood sugar level is regulated by **two hormones** called **insulin and glucagon**, which are both produced in the **pancreas**. When blood sugar levels are **too high**, **insulin** is released from the pancreas and works to **decrease blood sugar** levels by encouraging cells to absorb glucose from the blood to be used in **respiration** or **converted to glycogen** for storage. Respiration rate is also increased. **Glucagon and insulin are antagonistic, which means that they function opposingly. Consequently, when blood sugar levels get too low, glucagon is released to increase it. Glucagon works by decreasing respiratory rate and increasing the breakdown of glycogen into glucose.**

Diabetes

In some people, blood sugar level is not regulated sufficiently. This disease is known as diabetes. There are two types of diabetes, type 1 and type 2:

- **Type one diabetes** is caused by **an inability to produce insulin**. This is because the cells that produce insulin in the pancreas are destroyed by antibodies in an **autoimmune response**. This results in high blood glucose levels. Type one diabetes can be managed by **injecting insulin** and **restricting the amount of carbohydrate** in the diet.

- **Type two diabetes** is usually caused by the body **losing its responsiveness** to insulin. This means that not enough glucose is taken up by cells, leading to high blood sugar levels. It can also be caused by **insufficient insulin production** in the pancreas. Type two diabetes is usually **less severe** than type one and is developed most commonly in **older or obese** people. It can be managed by **changing the diet** to restrict carbohydrate intake and **increasing exercise**.

Structure and functions of the eye

- **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. When light hits these cells, they send nerve impulses to the brain, allowing an image to be formed.

Focusing the eye

The eye can **focus** on both near and far objects. This is achieved by **changing the shape of the lens** and is controlled by **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**.

Pupil reflex
The **pupil** of the eye can **expand and contract** to **control the amount of light** that enters the eye. At low light intensities, the pupil **dilates** to allow more light to enter the eye. At high light intensities, the pupil **constricts** to limit the amount of light entering the. This is to prevent the eye being damaged by the bright light.

Common eye defects (biology only)

- **Short-sightedness** - Short sightedness is caused by the lens being too thick and curved, or by the eyeball being elongated, thus the picture is focused behind the retina. This means that objects far away are blurry.
- **Long-sightedness** - Long sightedness is caused by the eyeball being too short or by the lens becoming less elastic, which is usually related to age. This causes the image to focus in front of the retina, so objects close by are blurry. Both long-sightedness and short-sightedness can be corrected by wearing glasses or contact lenses.
- **Cataracts** - Cataracts develop slowly and cause the lens to become cloudy due to a build-up of protein, which restricts vision. They are commonly age-related but can also be a result of diabetes or appear after an injury to the eye. They can be removed using laser eye surgery, or invasive surgery to replace the lens.

Neurone damage (biology only)
Once a neurone becomes differentiated it cannot divide by mitosis. This means that they cannot divide to replace damaged or dead neurones. Consequently, nervous system damage can lead to debilitating illnesses that are extremely difficult or impossible to treat. Examples of these diseases includes Alzheimer's disease and motor neurone disease.

In the future, stem cells may be able to replace damaged neurones. This may offer a cure to many nervous system diseases that are currently untreatable. However, there are contentious ethical issues regarding the use of stem cells, as they must be harvested from embryos, which are destroyed in the process.