OCR (A) Biology GCSE

Topic 2: Scaling up

Notes

(Content in bold is for higher tier only)

Supplying the cell
Transporting substances (2.1a)

Diffusion

- Diffusion is the spreading out of the particles resulting in a net movement from an area of higher concentration to an area of lower concentration.
- It is a passive process as no energy is required.
- The molecules have to be small in order to be able to move across, for example oxygen, glucose, amino acids and water, but larger molecules such as starch and proteins cannot.

Examples in living organisms:

- Single-celled organisms can use diffusion to transport molecules into their body from the air- this is because they have a relatively large surface area to volume ratio. Due to their low metabolic demands, diffusion across the surface of the organism is sufficient enough to meet its needs.
- In multicellular organisms the surface area to volume ratio is small so they cannot rely on diffusion alone. Instead, surfaces and organ systems have a number of adaptations that allows molecules to be transported in and out of cells. Examples include alveoli in the lungs, villi in the small intestines and root hair cells in plants.

Many factors affect the rate of diffusion:

Factor	Effect
Concentration gradient (difference in concentrations)	The greater the difference in concentration, the faster the rate of diffusion. This is because more particles are randomly moving down the gradient than are moving against it.
Temperature	The greater the temperature, the greater the movement of particles, resulting in more collisions and therefore a faster rate of diffusion.
Surface area of the membrane	The greater the surface area, the more space for particles to move through, resulting in a faster rate of diffusion.

Osmosis

- Osmosis is the movement of water from a less concentrated solution to a more concentrated one through a partially permeable membrane.
- A dilute solution of sugar has a high concentration of water (and therefore a high water potential). A concentrated solution of sugar has a low concentration of water (and therefore a low water potential). Water moves from a dilute solution to a concentrated solution because it

moves from an area of high water potential to low water potential- down the concentration gradient.
- It is passive, as it does not use energy.
- If the concentration of sugar in an external solution is the same as the internal, there will be no movement and the solution is said to be isotonic to the cell
- If the concentration of sugar in external solution is higher than the internal, water moves out, and the solution is said to be hypertonic to the cell
- If the concentration of sugar in external solution is lower than the internal, water moves in, and the solution is said to be hypotonic to the cell

Examples in living organisms:
- Osmosis in animals:
    - If the external solution is more dilute (higher water potential), it will move into animal cells causing them to burst.
    - If the external solution is more concentrated (lower water potential), excess water will leave the cell causing it to become shrivelled.
- Osmosis in plants:
    - If the external solution is more dilute, water will move into the cell and into the vacuole, causing it to swell, resulting in pressure called turgor (essential in keeping the leaves and stems of plants rigid).
    - If the external solution is less dilute, water will move out of the cell and they will become soft. Eventually the cell membrane will move away from the cell wall (called plasmolysis) and it will die.

Active transport
- Active transport is the movement of particles from an area of lower concentration to an area of higher concentration, i.e. against the concentration gradient.
- This requires energy from respiration as it is working against the gradient, which is why it is called active.

Examples in living organisms:
- In root hair cells:
    - They take up water and mineral ions (for healthy growth) from the soil
    - Mineral ions are usually in higher concentrations in the cells, meaning diffusion cannot take place
    - This requires energy from respiration to work
- In the gut:
    - Substances such as glucose and amino acids from your food have to move from your gut into your bloodstream
    - Sometimes there can be a lower concentration of sugar molecules in the gut than the blood, meaning diffusion cannot take place
    - Active transport is required to move the sugar to the blood against its concentration gradient

Mitosis (2.1b)

Mitosis is a type of cell division where one cell divides to form two identical daughter cells. The cell cycle is a series of steps that the cell has to undergo in order to do this.

Stage 1 (Interphase): In this stage the cell grows, organelles (such as ribosome and mitochondria) grow and increase in number, the synthesis of proteins occurs, all 46 chromosomes are replicated (forming the characteristic 'X' shape) and energy stores are increased

Stage 2 (Mitosis): The chromosomes line up at the equator of the cell and spindle fibres pull each chromosome of the 'X' to either side of the cell.

Stage 3 (Cytokinesis): Two identical daughter cells form when the cytoplasm and cell membranes divide, each containing the same 46 chromosomes as the original cell.

Cell division by mitosis in multicellular organisms is important in their growth and development, and when replacing damaged cells. Mitosis is also a vital part of asexual reproduction, as this type of reproduction only involves one organism, so to produce offspring it simply replicates its own cells.

Differentiation and specialisation (2.1c)

Specialised cells

- Cells specialise by undergoing differentiation: a process that involves the cell gaining new sub-cellular structures in order for it to be suited to its role.
- Cells can either differentiate once early on or have the ability to differentiate their whole life (these are called stem cells).
- In animals, most cells only differentiate once, but in plants many cells retain the ability.

Examples of specialised cells in animals

Sperm cells: specialised to carry the male's DNA to the egg cell (ovum) for successful reproduction

- Streamlined head and long tail to aid swimming
- Many mitochondria (where respiration happens) which supply the energy to allow the cell to move
- The acrosome (top of the head) has digestive enzymes which break down the outer layers of membrane of the egg cell

Nerve cells: specialised to transmit electrical signals quickly from one place in the body to another

- The axon is long, enabling the impulses to be carried along long distances
- Having lots of extensions from the cell body (called dendrites) means branched connections can form with other nerve cells
- The nerve endings have many mitochondria which supply the energy to make special transmitter chemicals called neurotransmitters. These allow the impulse to be passed from one cell to another.

Muscle cells: specialised to contract quickly to move bones (striated muscle) or simply to squeeze (smooth muscle, e.g found in blood vessels so blood pressure can be varied), therefore causing movement

- Special proteins (myosin and actin) slide over each other, causing the muscle to contract
- Lots of mitochondria to provide energy from respiration for contraction
- They can store a chemical called glycogen that is used in respiration by mitochondria

Examples of specialised cells in plants

Root hair cells: specialised to take up water by osmosis and mineral ions by active transport from the soil as they are found in the tips of roots

- Have a large surface area due to root hairs, meaning more water can move in
- The large permanent vacuole affects the speed of movement of water from the soil to the cell
- Mitochondria to provide energy from respiration for the active transport of mineral ions into the root hair cell

Xylem cells: specialised to transport water and mineral ions up the plant from the roots to the shoots

- Upon formation, a chemical called lignin is deposited which causes the cells to die. They become hollow and are joined end-to-end to form a continuous tube so water and mineral ions can move through
- Lignin is deposited in spirals which helps the cells withstand the pressure from the movement of water

Phloem cells: specialised to carry the products of photosynthesis (food) to all parts of the plants

- Cell walls of each cell form structures called sieve plates when they break down, allowing the movement of substances from cell to cell
- Despite losing many sub-cellular structures, the energy these cells need to be alive is supplied by the mitochondria of the companion cells.

Stem cells (2.1d-f)

Characteristics of stem cells

- A stem cell is an undifferentiated cell which can undergo division to produce many more similar cells
- Some of these will differentiate to have different functions, such as the specialised cells mentioned above
- They are important in development, growth and repair

Types of stem cells

1. Embryonic stem cells
    - Form when an egg and sperm cell fuse to form a zygote
    - They can differentiate into any type of cell in the body

- Scientists can clone these cells (though culturing them) and direct them to differentiate into almost any cell in the body
- These could potentially be used to replace insulin-producing cells in those suffering from diabetes, new neural cells for diseases such as Alzheimer's, or nerve cells for those paralysed with spinal cord injuries

2. Adult stem cells
   - If found in bone marrow they can form many types of cells (not any type, like embryonic stem cells can) including blood cells

3. Meristems in plants
   - Found in root and shoot tips
   - They can differentiate into any type of plant, and have this ability throughout the life of the plant
   - They can be used to make clones of the plant- this may be necessary if the parent plant has certain desirable features (such as disease resistance), for research or to save a rare plant from extinction

The challenges of size

Exchange systems (2.2a and b)

As mentioned before, multicellular organisms have a small surface area to volume ratio compared to the amount of substances they need to exchange.

Surface area to volume ratio

The size of the surface area of the organism compared to its volume

- Calculated by finding the volume (length x width x height) and the surface area (length x width), and writing the ratio in the smallest whole numbers
- If this is large, the organism is less likely to require specialised exchange surfaces and a transport system because the rate of diffusion is sufficient in supplying and removing the necessary gases
- E.g 15 (surface area): 5 (volume) is written as 3:1

Multicellular organisms have had to adapt to increase this ratio as much as possible...

Adaptation	Why?	Example
Having a large surface area	The greater the surface area, the more particles can move through, resulting in a faster rate of diffusion	**Lungs**: the small, spherical alveoli (sites of gaseous exchange) in the lungs create a very large surface area (approximately $75m^2$ in humans). **Small intestine**: the cells of the small intestine have

		millions of villi, which are projections which increase the surface area. This means digested food can be absorbed into the blood faster **Fish gills**: these contain lamellae to increase the surface area. **Leaves**: the flattened shape increases the surface area. The air spaces inside the leaf increase the surface area, so more carbon dioxide can enter cells.
Having a thin membrane	Provides a short diffusion pathway, allowing the process to occur faster	**Lungs**: alveoli and capillary walls are extremely thin. **Small intestine**: villi have a single layer of surface cell.
Having an efficient blood supply OR having good ventilation (in animals)	Creates a steep concentration gradient, so diffusion occurs faster	**Lungs**: the lungs constantly supply oxygen to make the blood from alveoli capillaries oxygenated, by exchanging it for carbon dioxide that can be breathed out. This is a constant process meaning the concentration gradient is always steep. **Fish**: water flows in one direction and blood flows in the other - this means that a steep concentration gradient is maintained as the concentration of oxygen is always much higher in the water - so it will diffuse across.

Human circulatory system (2.2c-e)

The heart is an organ in the circulatory system. The circulatory system carries oxygen and nutrients to every cell in the body and removes the waste products.

The heart pumps blood around the body in a double circulatory system. This means there are two circuits. Mammals require this double system because the metabolic rate is higher and so need a faster system.

- System 1: Deoxygenated blood flows into the right atrium and then into the right ventricle which pumps it to the lungs to undergo gaseous exchange
- System 2: Oxygenated blood flows into the left atrium and then into the left ventricle which pumps oxygenated blood around the body

Structure of the heart

- Muscular walls to provide a strong heartbeat
- The muscular wall of the left ventricle is thicker because blood needs to be pumped all around the body rather than just to the lung like the right ventricle.
- 4 chambers that separate the oxygenated blood from the deoxygenated blood: 2 atria above and 2 ventricles below

- Valves to make sure blood does not flow backwards
- Coronary arteries cover the heart to provide its own oxygenated blood supply

Process:

1. Blood flows into the right atrium through the vena cava, and left atrium through the pulmonary vein.
2. The atria contract forcing the blood into the ventricles.
3. The ventricles then contract, pushing the blood in the right ventricle into the pulmonary artery to be taken to the lungs, and blood in the left ventricle to the aorta to be taken around the body.
4. As this happens, valves close to make sure the blood does not flow backwards.

Structure of blood vessels

Arteries carry blood AWAY from the heart

- Layers of muscle in the walls make them strong
- Elastic fibres allow them to stretch
- This helps the vessels withstand the high pressure created by the pumping of the heart

Veins carry blood TOWARDS the heart

- The lumen (the actual tube in which blood flows through) is wide to allow the low pressure blood to flow through
- They have valves to ensure the blood flows in the right direction

Capillaries allow the blood to flow very close to cells to enable substances to move between them

- One cell thick walls create a short diffusion pathway
- Permeable walls so substances can move across them

Structure of blood

Red blood cells:

- Contain haemoglobin: a red protein that combines with oxygen to allow for transport
- No nucleus: to create more space for haemoglobin
- Biconcave shape: to maximise surface area for oxygen to be absorbed
- Flexible: so they can fit through very narrow blood vessels

Plasma:

- Plasma is the liquid which carries all of the components of blood, such as blood cells, platelets, amino acids, urea etc.
- Plasma is mainly made up of water and many substances that need to be transported around the body, e.g. carbon dioxide, urea, are water-soluble

Plant exchange systems (2.2f-j)

Transpiration and water uptake

Transpiration is the loss of water of water vapour from the leaves and stems of the plant. It is a consequence of gaseous exchange, as the stomata are open so that this can occur.

- Water also evaporates at the open stomata
- As water molecules are attracted to each other, when some molecules leave the plant the rest are pulled up through the xylem
- This results in more water being taken up from the soil resulting in a continuous transpiration stream through the plant

Xylem:

Water travels up xylem from the roots into the leaves of the plant to replace the water that has been lost due to transpiration. Xylem is adapted in many ways:

- A chemical called lignin is deposited which causes the cells to die.
- These cells then become hollow and join end-to-end to form a continuous tube for water and mineral ions to travel through from the roots
- Water molecules are attracted to each other by hydrogen bonding - creating a continuous column of water up the plant
- The water evaporates from the leaves of the plant, creating the transpiration stream.
- Lignin strengthens the plant to help it withstand the pressure of the water movement
- Lignin contains bordered pits, which are holes to allow specific areas for water and therefore minerals to enter the plant

Root hair cells:

Water is taken up by plants through root hair cells, which were detailed in the 2.1c. These are specialised cells with a very large surface area to absorb water via osmosis. If the rate of transpiration increases then the rate of water uptake will also increase as the plant attempts to replenish the loss.

Guard cells:

- Open and close stomata
- They are kidney shaped, with thin outer walls and thick inner walls
- When lots of water is available to the plant, the cells fill and change shape, opening stomata (they are also light sensitive)
- This allows gases to be exchanged and more water to leave the plant via evaporation

More stomata are found on the bottom of the leaf, allowing gases to be exchanged whilst minimising water loss by evaporation as the lower surface is shaded and cooler.

Factors affecting water uptake:

Factor	Effect
Increase in light intensity	This leads to an increased rate of photosynthesis, so more stomata open to allow gaseous exchange to occur. This means more water can evaporate, leading to an increased rate of transpiration and so uptake.
Increase in temperature	The molecules move faster, resulting in evaporation happening at a faster rate and therefore the rate of transpiration increases. The rate of photosynthesis increases, meaning more stomata are open for gaseous exchange, so more water evaporates and the rate of transpiration increases. Therefore, water uptake also increases.
Increased air movement (wind)	If more air is moving away from the leaf due to it being blown away, then the concentration of water vapour surrounding the leaf will be lower. This will mean there will be a steeper concentration gradient resulting in diffusion happening faster. This will increase the rate of transpiration and also water uptake.
Increase in humidity	If the relative humidity is high, then there will be a reduced concentration gradient between the concentrations of water vapour inside and outside the leaf, resulting in a slower rate of diffusion. This will decrease the rate of transpiration and water uptake.

A potometer can be used to investigate how these factors affect water uptake. It is set up underwater to remove air bubbles in the xylem so that there is a continuous stream of water and the system is made airtight, apart from a singular bubble of air. The distance this air bubble in the capillary tube moves over time is measured. If it moves faster then it means that there is a greater rate of water uptake and therefore rate of transpiration. An environmental condition, such as light intensity, is changed each time the experiment is run in order to see how it affects the plant.

Translocation

Translocation is the movement of food substances made in the leaves up or down the phloem, for use immediately or storage

Phloem adaptations:

- Found in the roots, stems and leaves
- Elongated cells with holes in the cell walls (the end walls are called sieve plates)
- Many organelles from the cells are removed so cell sap can move through.
    - However, there are many mitochondria in companion cells which provide the energy the cells require
- Food substances can be moved in both directions (translocation), from the leaves where they are made for use, or from storage (underground) to parts of the plant that need it.