WJEC (England) Biology GCSE

Topic 2: Transport Systems

Notes

2.1 Transport in cells

Diffusion

Diffusion is the net movement of particles from an area of high concentration to an area of low concentration down the concentration gradient. This is a passive process, meaning that it does not require energy. Solutes and gases diffuse in and out of cells across the cell membrane. The cell membrane, along with the cell wall in plant cells, controls what substances enter and exit the cell.

Factors affecting rate of diffusion:

- Surface area - As the surface area increases, the rate of diffusion increases as there is more space available for the substances to diffuse through.
- Temperature - As temperature increases, the rate of diffusion increases. This is because the molecules gain kinetic energy and thus move faster.
- Concentration gradient - As the concentration gradient increases, rate of diffusion increases.
- Diffusion distance - A greater diffusion distance slows the rate of diffusion as molecules must travel further.

Osmosis

Osmosis is the diffusion of water molecules from a region of higher water (low solute) concentration to a region of lower water (higher solute) concentration through a selectively permeable membrane. Selectively permeable membranes are only permeable to certain substances, meaning that they choose which substances can move across the membrane and which cannot.

Water moves in and out of cells through the cell membrane via osmosis. Water is important for the cell and has a number of roles:

- It provides support for the cell structure through maintaining the turgor pressure.
- It provides a medium in which metabolic reactions occur.
- Water has a high specific heat capacity, thus acts as a temperature buffer. This is important as it maintains the optimum temperature for enzyme reactions.

Active transport

Active transport is the movement of molecules against a concentration gradient using energy from respiration. Molecules are actively transported from regions of low concentration to regions of higher concentration. Examples include the uptake of mineral ions from the soil into the root hair cells of plants, and the uptake of glucose into the blood in the small intestine.

Exchange surfaces

Exchange surfaces are specialised areas which allow the exchange of substances. This includes the exchange of oxygen, carbon dioxide and mineral ions, as well as waste products such as urea. Exchange is crucial to allow molecules required in the cell to enter, and waste products to exit so that they can be disposed of. If this did not happen, waste products such as urea and carbon dioxide can build up and become harmful.

Exchange surfaces are adapted to make exchanges as efficient as possible. Adaptations include:

- A short diffusion distance - cells acting as exchange surfaces are very thin to reduce the distance that substances must travel, making diffusion faster.
- 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.
- 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 being used up in a cellular reaction.
- Being moist - this allows gases to dissolve before diffusing across the membrane.

2.2 Transport systems in humans

The circulatory system

The circulatory system acts as the main transport system in humans. This is made up of blood vessels, such as arteries, veins and capillaries, in which blood travels around the body. Humans have a double circulatory system, meaning that blood passes through the heart twice each circuit of the body. This means that the heart must have four chambers to keep oxygenated and deoxygenated blood separate. Mammals require double circulatory systems as they are larger and have a greater need for oxygen to use in respiration. Double circulatory systems are more efficient at supplying oxygen and can maintain a high blood pressure.

The heart structure and function

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. 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 and thinnest type of blood vessel and hence are where exchange usually takes place. There is an extensive capillary network, meaning that every cell in the body is near to a capillary.

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.

The blood

The blood is very important in the body as it transports essential substances, such as hormones, oxygen and nutrients, to the cells, as well as removing waste substances such as carbon dioxide and urea. It also protects against infection and repairs damage.

There are four main components of blood:

- Plasma - The liquid in blood vessels which contains blood cells, nutrients, hormones, water, urea and antibodies.
- Red blood cells - contain haemoglobin (protein) which binds to oxygen, allowing it to be transported around the body to cells.
- White blood cells - play a major role in fighting off infection. Some white blood cells produce antibodies, which bind to pathogens and cause them to clump together. This leads to pathogen destruction or marks them out for further attack by the immune system.
- Platelets - Involved in blood clotting. Blood clotting occurs when a blood vessel breaks due to injury. Platelets stick to the broken vessel wall and clump together, blocking the cut. This forms a scab and prevents bleeding by blocking the cut. This allows the vessel to heal, as well as preventing pathogens from entering the blood vessel.

2.3 Transport systems in plants

Leaf structure and function

- Waxy Cuticle - a waterproof layer that helps minimise water loss from the leaf.
- Lower epidermis - the lower part of the leaf, contains the stomata and regulates gas exchange.
- Stomata - located at the bottom of the leaf, allow gases to diffuse into the leaf and water vapour to diffuse out.
- Palisade layer - the top layer of the leaf, made up of palisade cells. These cells contain chloroplasts for photosynthesis.
- Spongy layer - loosely packed cells with lots of air spaces. This allows fast diffusion of gases in the leaf.
- Xylem - transports water through the plant in transpiration. This is used in photosynthesis.
- Phloem - transports sugars and food nutrients up and down the plant in translocation.

Xylem and phloem

Plants have a transport system made up of xylem and phloem vessels. These transport substances through the plant:

- The xylem is used to transport water through the plant from the roots in transpiration. This water is used in cellular reactions such as photosynthesis. The xylem is adapted for this by being made from hollowed-out dead cells, which have their ends removed to make a tube for water to pass through. These cells are also impermeable to water.
- The phloem is made of living cells and is used to transport sugars and food nutrients in translocation. This is important as these are used in metabolic reactions, such as respiration. When the sugar is not being used, it is converted into starch for storage. These vessels are both strengthened with lignin.

Stomata and guard cells

Stomata are located on the lower side of leaves and allow the diffusion of carbon dioxide into, and water vapour and oxygen out of, the leaf. Guard cells surround the stomata and can control the opening and closing of it to limit water loss from the plant; when there is a limited water supply, the guard cells cause the stomata to close to prevent water loss. Plants in hot places often have fewer stomata to reduce water loss and some plants, for example cacti, only open their stomata at night.

Root hair cells

Water is taken up by root hair cells via osmosis. The water then moves into the root cortex cells (as the root hair cells now have a higher water potential than the cortex cells), before entering the xylem vessel where it is drawn up the stem to the leaves. Root hair cells are adapted for efficient water uptake by having a large surface area, which increases the rate of osmosis into the root. They also have a thin wall, so the diffusion distance is very short.

Mineral salts are also taken up by root hair cells. Due to the low concentration of minerals in the soil, they must move up the concentration gradient into the root from a low concentration to a high concentration. This therefore involves active transport and requires energy. Root hair cells are highly adapted to carry out active transport efficiently:

- They have a large surface area.
- They have a large concentration of mitochondria, which carry out respiration to produce energy for active transport.
- They have a thin cell membrane to speed up the rate of diffusion and active transport.

Transpiration

Transpiration is the loss of water vapour from the mesophyll cell surface due to evaporation. This water vapour then exits the plant via the stomata. Water molecules are consequently drawn up the xylem by transpiration pull (not osmosis). Water molecules are cohesive, meaning they stick together. This means that as the water evaporates at the leaf and diffuses out of the stomata, more water is drawn up the plant from the roots.

Environmental factors that affect the rate of transpiration and water uptake:

- Light intensity - when there is a high light intensity, photosynthesis rate is high, meaning that the stomata are open to ensure there is carbon dioxide available. Consequently, the transpiration rate is high, meaning that the rate of water uptake must increase to replace the water lost.
- Air movement - Moist air is often trapped around the stomata, which decreases the difference in water vapour concentration inside and outside of the plant. This means that the rate of transpiration, and hence water uptake, is low. Similarly, if there is a humid atmosphere there is a low water uptake. If there is lots of air movement, this moist air is blown away from the leaf, meaning that water uptake increases.
- Temperature - At warm temperatures, the rate of evaporation is high, so the rate of water uptake is high. In addition, the rate of photosynthesis is high, meaning that the stomata will be open, increasing transpiration.