AQA Biology A-level

Topic 3: Organisms exchange substances with their environment

Notes

Exchange

The need for specialised exchange surfaces arises as the size of the organism, and its surface area to volume ratio increases. In the case of single celled organisms, the substances can easily enter the cell as the distance that needs to be crossed over is short. However, in multicellular organisms that distance is much larger due to a higher surface area to volume ratio. As a result of that, multicellular organisms required specialised exchange surfaces for efficient gas exchange of carbon dioxide and oxygen.

Features of an efficient exchange surface include large surface area, for instance the root hair cells or folded membranes, such as those of the mitochondria. An efficient exchange surface should also be thin to ensure that the distance that needs to be crossed by the substance is short. The exchange surface also requires a good blood supply/ventilation to maintain a steep gradient, for example that of the alveoli.

Ventilation and gas exchange in fish, insects and plants.

Fish

Fish have a small surface area to volume ratio for gas exchange, apart from this they also have an impermeable membrane so gases can't diffuse through their skin. This means that fish therefore need a specialised gas exchange surface. Bony fish have four pairs of gills, each gill supported by an arch. Along each arch there are multiple projections called gill filaments, with lamellae on them which participate in gas exchange. Blood and water flow across the lamellae in a counter current direction meaning they flow in the opposite direction to one another. This ensures that a steep diffusion gradient is maintained so that the maximum amount of oxygen is diffusing into the deoxygenated blood from the water. The projections are held apart by water flow. Therefore, in the absence of water they stick together, thus meaning fish cannot survive very long out of water.

Ventilation is required to maintain a continuous unidirectional flow. Ventilation begins with the fish opening its mouth followed by lowering the floor of buccal cavity. This enables water to flow in. Afterwards, fish closes its mouth, causing the buccal cavity floor to raise, thus increasing the pressure. The water is forced over the gill filaments by the difference in pressure between the mouth cavity and opercular cavity. The operculum acts as a valve and pump and lets water out and pumps it in.

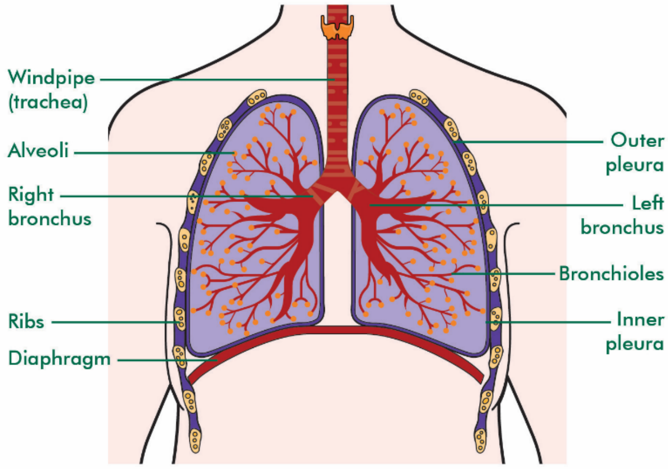
Terrestrial Insects

Insects do not possess a transport system therefore oxygen needs to be transported directly to tissues undergoing respiration. This is achieved with the help of spiracles, small openings of tubes, either bigger trachea or smaller tracheoles, which run into the body of an insect and supply it with the required gases. Gases move in and out through diffusion, mass transport as a result of muscle contraction and as a result of volume changes in the tracheoles.

Plants

Finally plants are adapted to efficient gas exchange through many adaptations in their leaves. Leaves have many small holes called stomata which allow gases to enter and exit the leaves. The large number of these means no cell is far from the stomata, reducing the diffusion distance. Leaves also possess air spaces to allow gases to move around the leaf and easily come into contact with photosynthesising mesophyll cells.

Mammalian gaseous exchange system



The lungs are a pair of lobed structures with a large surface area located in the chest cavity that are able to inflate. The lungs are surrounded by the rib cage which serves to protect them. A lubricating substance is secreted to prevent friction between the rib cage and lungs during inflation and deflation. External and internal intercostal muscles between the ribs contract to raise and lower the ribcage respectively. A structure called the diaphragm separates the lungs from abdomen area.

The air enters through the nose, along the trachea, bronchi and bronchioles which are structures well adapted to their role in enabling passage of air into the lungs. The gaseous exchange takes place in the walls of alveoli, which are tiny sacs filled with air.

The trachea, bronchi and bronchioles enable the flow of air into and out of the lungs. The airways are held open with the help of a rings of cartilage, incomplete in the trachea to allow passage of food down the oesophagus behind the trachea.

Trachea and bronchi are similar in structure, with the exception of size - bronchi are narrower. They are composed of several layers which together make up a thick wall. The wall is mostly composed of cartilage, in the form of incomplete C rings. The inside surface of the cartilage is a layer of glandular and connective tissue, elastic fibres, smooth muscle and blood vessels. This is referred to as the 'loose tissue'. The inner lining is an epithelial layer composed of ciliated epithelium and goblet cells.

The bronchioles are narrower than the bronchi. Only the larger bronchioles contain cartilage. Their wall is made out of smooth muscle and elastic fibres. The smallest of bronchioles have alveoli clusters at the ends. The alveoli are adapted for transport for the following reasons:

- The alveoli are very thin being only around one cell thick. These are surrounded by capillaries which are also only one cell thick. This reduces the diffusion pathway for gases.
- The constant blood supply by capillaries means that a steep concentration gradient is constantly maintained.
- The are a large number of alveoli (~300 million), collectively giving a surface area of ~70m^2.

Structures and functions of mammalian gaseous exchange system include:

- **Cartilage** - involved in supporting the trachea and bronchi, plays an important role in preventing the lungs from collapsing in the event of pressure drop during exhalation.

- **Ciliated epithelium** - present in bronchi, bronchioles and trachea, involved in moving mucus along to prevent lung infection by moving it towards the throat where it can be swallowed.

- **Goblet cells** - cells present in the trachea, bronchi and bronchioles involved in mucus secretion to trap bacteria and dust to reduce the risk of infection with the help of lysozymes which digest bacteria.
- **Smooth muscle** - their ability to contract enables them to play a role in constricting the airway, thus controlling its diameter as a result and thus controlling the flow of air to and from the alveoli.

- **Elastic fibres** - stretch when we exhale and recoil when we inhale thus controlling the flow of air.

Ventilation

The flow of air in and out of the alveoli is referred to as ventilation and is composed of two stages; inspiration and expiration. This process occurs with the help of two sets of muscles, the intercostal muscles and diaphragm.

Inspiration

During inspiration, the external intercostal muscles contract whereas the internal muscles relax, as a result this causes the ribs to raise upwards. The diaphragm contracts and flattens. In combination, the intercostal muscles and diaphragm cause the volume inside the thorax to increase, thus lowering the pressure. The difference between the pressure inside the lungs and atmospheric pressure creates a gradient, thus causing the air to be forced into the lungs.

Expiration

During expiration, the internal intercostal muscles contract whereas the external muscles relax therefore lowering the rib cage. The diaphragm relaxes and raises upwards. This action in combination decrease the volume inside the thorax, therefore increasing the pressure, forcing the air out of the lungs.

Spirometer

A spirometer is a device used to measure lung volume. A person using a spirometer breathes in and out of the airtight chamber, thus causing it to move up and down, leaving a trace on a graph which can then be interpreted.

Vital capacity - the maximum volume of air that can be inhaled or exhaled in a single breath. Varies depending on gender, age, size as well as height.

Tidal volume – the volume of air we breathe in and out at each breath at rest

Breathing rate – the number of breaths per minute, can be calculated from the spirometer trace by counting the number of peaks or troughs in a minute

The volume of air which is always present in the lungs is known as the residual volume. The tidal volume can be exceeded, in cases such as during exercise where the inspiratory reserve volume is reached in an attempt to increase the amount of air breathed in. Similarly, the expiratory reserve volume is the additional volume of air that can be exhaled on top of the tidal volume.

Digestion and absorption

Digestion is the hydrolysis of large biological molecules into smaller molecules which can be absorbed across cell membranes.

- Carbohydrates are digested by many different enzymes. Amylases in the mouth digest larger polymers, maltases in the ileum break down monosaccharides, and sucrases and lactases break down the dissacharides sucrose and lactose respectively.

- Lipids are digested by lipases which hydrolyse the ester bond between the monoglycerides and fatty acid. Before being broken down in the ileum, lipids are emulsified into micelles by bile salts released by the liver. Emulsification increases the surface area and speeds up the chemical reaction.

- Proteins are digested by enzymes called peptidases of which they are divided into 3 main groups:

  - endopeptidases - hydrolyse peptide bonds between specific amino acids in the middle of a polypeptide.

  - exopeptidases - hydrolyse bonds at ends of a polypeptides

  - dipeptidases - break dipeptides into individual amino acids

Products of digestion are absorbed by cells lining the ileum of mammals. For example, amino acids are absorbed by facilitated diffusion through specific carrier molecule in the surface membrane of epithelial cells. With each amino acid, one Na+ is also taken up, therefore amino acid absorption occurs via a process known as co-transport. A diffusion gradient for Na+ is maintained by their active transport through the base of epithelial cells where amino acids pass by facilitated diffusion.

Monoglycerides and fatty acids are polar so they can easily diffuse across the cell membrane into the epithelial cells lining the epithelium. Once inside they are transported to the endoplasmic reticulum where they are reformed into triglycerides again. After this they move out of the cells by vesicles into the lymph system.

Haemoglobin

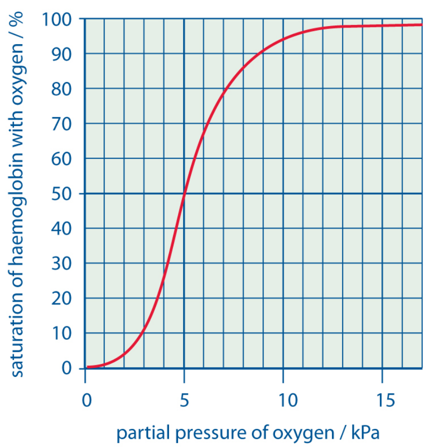
Haemoglobin is a water soluble globular protein which consists of two beta polypeptide chains and two alpha helices. Each molecule forms a complex containing a haem group. It carries oxygen in the blood as oxygen can bind to the haem (Fe2+) group. Each molecule can carry four oxygen molecules.

The affinity of oxygen for haemoglobin varies depending on the partial pressure of oxygen which is a measure of oxygen concentration. The greater the concentration of dissolved oxygen in cells the greater the partial pressure. Therefore, as partial pressure increases, the affinity of haemoglobin for oxygen increases, that is, oxygen binds to haemoglobin tightly. This occurs in the lungs in the process known as loading. During respiration, oxygen is used up and therefore the partial pressure decreases, thus decreasing the affinity of oxygen for haemoglobin. As a result of that, oxygen is released in respiring tissues where it is needed. After the unloading process, the haemoglobin returns to the lungs where it binds to oxygen again.

Dissociation curves illustrate the change in haemoglobin saturation as partial pressure changes. The saturation of haemoglobin is affected by its affinity for oxygen, therefore in the case where partial pressure is high, haemoglobin has high affinity for oxygen and is therefore highly saturated, and vice versa.

Saturation can also have an effect on affinity, as after binding to the first oxygen molecule, the affinity of haemoglobin for oxygen increases due to a change in shape, thus making it easier for the other oxygen molecules to bind.

The graph on the right shows an oxygen disassociation curve. Initially the curve is shallow because it is hard for the first oxygen molecule to bind. Once it has bound though it changes the shape making it easier for oxygen molecules two and three to bind, hence the steep increase. This is called positive cooperativity. Finally the gradient begins to flatten out because the likelihood of the fourth oxygen finding a binding site is low.



Fetal heamoglobin has a different affinity for oxygen compared to adult haemoglobin, as in needs to be better at absorbing oxygen because by the time oxygen reaches the placenta, the oxygen saturation of the blood has decreased. Therefore, fetal haemoglobin must have a higher affinity for oxygen in order for the foetus to survive at low partial pressure.

The affinity of haemoglobin for oxygen is also affected by the partial pressure of carbon dioxide. Carbon dioxide is released by respiring cells which require oxygen for the process to occur. Therefore, in the presence of carbon dioxide, the affinity of haemoglobin for oxygen decreases, thus causing it to be released. This is known as the Bohr effect. It does this because carbon dioxide creates slightly acidic conditions which change the shape of the haemoglobin protein, thus making it easier for the oxygen to be released.

Circulatory System of a Mammal

In large organisms the surface area to volume ratio is not large enough for diffusion alone to supply substances like oxygen, glucose and other molecules to cells where they are needed. Therefore a circulatory system is used.

There are many common features of a circulatory system, some of these are:

1. Suitable medium - in mammals the transport medium is the blood. It is water based so substances can easily dissolve into it.
2. Means of moving the medium - animals often have a pump known as the heart to maintain pressure differences around the body.
3. Mechanism to control flow around the body - valves are used in veins to prevent any backflow.
4. Close system of vessels - the circulatory system in most animals and plants is closed and is branched to deliver substances to all parts of the body.

In mammals the circulatory system is a closed double circulatory system. The heart at the centre has two pumps. One pumps bloods to the lungs to be oxygenated whilst the other is larger and stronger and pumps the oxygenated blood around the body to supply vital organs and tissues.

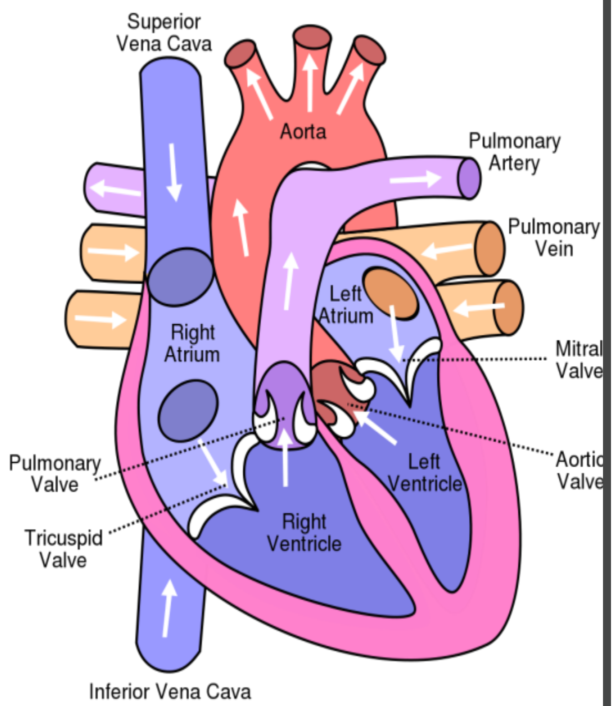
Structure of the Human Heart and the Cardiac Cycle

The heart is made up of two pumps each with two chambers. These are:

- an atrium - thin walled and elastic, the atrium can stretch when filled with blood.
- A ventricle - thick muscular wall to pump blood around the body or to the lungs.

Two separate pumps are needed in order to maintain blood pressure around the whole body. One pump would not be able to do this as the slow down of the blood as it passes the lungs would cause it to lose all pressure.

Between the atria and ventricles there are a set of valves. The left atrioventricular valve (bicuspid valve) and the right atrioventricular valve (tricuspid valve).



There are 4 main vessels connecting the heart these are:

1. *Aorta* - connected to the left ventricle and carries oxygenated blood to all parts of the body except the lungs.
2. *Pulmonary Artery* - connected to the right ventricle and carries deoxygenated blood to the lungs where it is oxygenated and the carbon dioxide is removed.
3. *Pulmonary Vein* - connected to the left atrium and brings oxygenated blood back from the lungs.
4. *Vena Cava* - connected to the right atrium and brings deoxygenated blood back from the tissues except the lungs.

The Cardiac Cycle

Due to the heart's ability to initiate its own contraction, it is referred to as **myogenic.** In the wall of the **right atrium** there is a region of specialised fibres called the **sinoatrial node** which is the pacemaker of the heart This initiates a wave of electrical stimulation which causes the **atria to contract at roughly the same time.**

The **ventricles** do not start contracting until the **atria** have finished due to the presence of tissue at the base of the atria which is **unable to conduct the wave of excitation (known as the septum)**. The electrical wave eventually reaches the **atrioventricular node** located between the two atria which passes on the excitation to ventricles, down the **bundle of His** to the apex of the heart. The bundle of His branches into **Purkyne fibres** which carry the wave upwards. This causes the ventricles to **contract**, thus emptying them. The ventricles contract at the apex in order to force the most blood possible upwards out of the aorta and pulmonary artery.

There are 3 stages of the cardiac cycle:

1) **Cardiac diastole** - atria and ventricles relax, **elastic recoil** of the heart **lowers the pressure inside the heart chambers** and blood returns to the heart from the vena cava and the pulmonary vein and fill the atria. Pressure increases in the atria until the **atrioventricular valves open** and blood flows into the ventricles. The relaxed aria and ventricles means that the semi-lunar valves are closed.

2) **Atrial systole** - The atria then contract forcing any remaining blood into the ventricles.

3) **Ventricular systole** - contraction of the ventricles causes the **atrioventricular valves to close** and **semi-lunar valves to open** thus allowing **blood to leave the left** ventricle through the **aorta** and right ventricle through the **pulmonary artery.**

Structure and Function of Blood Vessels

- Arteries - adapted to carrying blood away from the heart to the rest of the body, thick walled to withstand high blood pressure, contain elastic tissue which allows them to stretch and recoil thus smoothing blood flow. They also contain smooth muscle which enables them to vary blood flow, lined with smooth endothelium to reduce friction and ease the flow of blood.

- Arterioles - branch off arteries, have thinner and less muscular walls, their role is to feed blood into capillaries.

- Capillaries - smallest blood vessels, site of metabolic exchange, only one cell thick for fast exchange of substances.

- Venules - larger than capillaries but smaller than veins.

- Veins - carry blood from the body to the heart, contain a wide lumen to maximise the volume of blood carried to the heart. They are thin walled as blood is under low pressure and contain valves to prevent the back-flow of blood. A weak pulse of blood means there is little elastic tissue or smooth muscle as there is no need for stretching and recoiling.

The Function of Tissue Fluid

Tissue fluid is a liquid containing dissolved oxygen and nutrients which serves as a means of supplying the tissues with the essential solutes in exchange for waste products such as carbon dioxide.

Hydrostatic pressure is created when blood is pumped along the arteries, into arterioles and then capillaries. This pressure forces blood fluid out of the capillaries. Only substances which are small enough to escape through the gap in a capillary are components of the tissue fluid - this includes dissolved nutrients such as amino acids, fatty acids, ions in solution, glucose and oxygen. The fluid is referred to as tissue fluid, as described above.

The fluid is also acted on by hydrostatic pressure which pushes some of the fluid back into the capillaries. As both the tissue fluid and blood contain solutes, they have a negative water potential. Although the water potential of the tissue fluid is negative, it is less negative in comparison to the blood (the blood contains more solutes). Therefore, the tissue fluid is positive in comparison to the blood. This causes water to move down the water potential gradient from the tissue fluid to the blood by osmosis.

The remaining tissue fluid which is not pushed back into the capillaries is carried back via the lymphatic system. The lymphatic system contains lymph fluid, similar in content to tissue fluid. However, lymph fluid contains less oxygen and nutrients compared to tissue fluid, as its main purpose is to carry waste products. The lymph system also contains lymph nodes which filter out bacteria and foreign material from the fluid with the help of lymphocytes which destroy pathogens as part of the immune system defences.

Mass transport in plants

Plants require a **transport system** to ensure that all the cells of a plant receive a sufficient amount of **nutrients**. This is achieved through the combined action of **xylem tissue** which enables water as well as dissolved minerals to travel up the plant in the passive process of transpiration, and **phloem tissue** which enables sugars to reach all parts of the plant in the active process of **translocation.**

Vessels in Plants

The vascular bundle in the roots:

- Xylem and phloem are components of the **vascular bundle,** which enable the transport of substances as well as provide structural support.
- The xylem vessels are arranged in an **X shape** in the centre of the vascular bundle. This enables the plant to withstand various **mechanical forces** such as pulling.
- The X shape arrangement of xylem vessels is surrounded by **endodermis**, which is an outer layer of cells which supply xylem vessels with water.
- An inner layer of meristem cells known as the **pericycle.**

The vascular bundle in the stem:

- The xylem is located on the inside in **non-wooded plants** to provide support and flexibility to the stem.
- Phloem is found on the outside of the vascular bundle.
- There is a layer of **cambium** in between the xylem and phloem, which are meristem cells involved in the production of new xylem and phloem tissue.

The vascular bundle in the leaf:

- The vascular bundles forms the **midrib and veins** of a leaf.
- **Dicotyledonous leaves** have a network of **veins**, starting at the midrib and spreading outwards which are involved in transport and support.

Transpiration

Water moves through xylem vessels in plants, these have the following features:

- They transport water and minerals, and also serve to provide structural support.
- They are long cylinders made of **dead tissue** with **open ends**, therefore they can form a continuous column.
- Xylem vessels also contain pits which enable water to move sideways between the vessels.
- They are thickened with a tough substance called lignin, which is deposited in **spiral patterns** to enable the plant to remain flexible.

Transpiration is the process where plants absorb water through the roots, which then moves up through the plant and is released into the atmosphere as water vapour through pores in the leaves. Carbon dioxide enters, while water and oxygen exit through a leaf's stomata.

The transpiration stream, which is the movement of water up the stem, enables processes such as photosynthesis, growth and elongation as it supplies the plant with water which is necessary for all of these processes. Apart from this, the transpiration stream supplies the plant with the required minerals, whilst enabling it to control its temperature via evaporation of water.

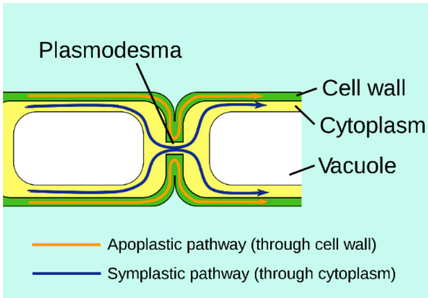
Transpiration involves osmosis, where water moves from the xylem to the mesophyll cells. Transpiration also involves evaporation from the surface of mesophyll cells into intercellular spaces and the diffusion of water vapour down a water vapour potential gradient out of the stomata.

The rate of transpiration can be investigated with the help of a potometer where water lost by the leaf is replaced by water in a capillary tube. Therefore, measuring the movement of the meniscus or a bubble can be used to determine the rate of transpiration. Factors which affect the rate of transpiration include **number of leaves, number/size or position of stomata, presence of waxy cuticle, the amount of light present, the temperature, humidity of the air, air movement and water availability.**

Xerophytes are plants adapted to living in dry conditions. They are able to survive in such conditions because of various adaptations which serve to minimise the water loss. Their adaptations include smaller leaves to reduce the surface area for water loss. Both densely packed mesophyll and thick waxy cuticle prevent water loss via evaporation. Moreover, xerophytes respond to low water availability by closing the stomata to prevent water loss. Apart from this, they also contain hairs and pits which serve as a means of trapping moist air, thus reducing the water vapour potential gradient. Xerophytes also roll their leaves in order to reduce the exposure of the lower epidermis to the atmosphere, thus trapping air that is moist.

Movement of water in the root

Water enters through root hair cells and moves into the xylem tissue located in the centre of the root. This movement occurs as a result of a water potential gradient, as the water potential is higher inside the soil than inside the root hair cells, due to the dissolved substances in the cell sap. Therefore, the purpose of root hair cells it to provide a large surface area for the movement of water to occur. Minerals are also absorbed through the root hair cells by active transport, as they need to be pumped against the concentration gradient.



There are two ways water is taken up by root hair cells and moves across the cortex of the root into the xylem:

- It can either occur via the symplast pathway where water enters the cytoplasm through the plasma membrane and passes from one cell to the next through plasmodesmata, the channels which connect the cytoplasm of one cell to the next.
- The other pathway is the apoplast pathway where the water moves through the water filled spaces between cellulose molecules in the cell walls. In this pathway, water doesn't pass through any plasma membranes therefore it can carry dissolved mineral ions and salts.

- When the water reaches a part of the root called the endodermis, it encounters a layer of suberin which is known as the Casparian strip, which cannot be penetrated by water.

- Therefore, in order for the water to cross the endodermis, the water that has been moving through the cell walls must now enter the symplast pathway.

- Once it has moved across the endodermis, the water continues down the water potential gradient from cell to cell until it reaches a pit in the xylem vessel which is the entry point of water.

Water moving in the xylem up the stem

The water is removed from the top of the xylem vessels into the mesophyll cells down the water potential gradient. The push of water upwards is aided by the root pressure which is where the action of the endodermis moving minerals into the xylem by active transport drives water into the xylem by osmosis, thus pushing it upwards.

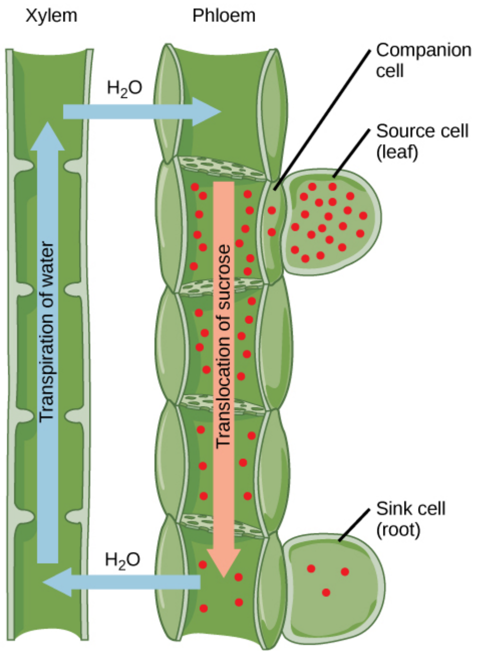
The flow of water is also maintained with the help of surface tension of water and the attractive forces between water molecules known as cohesion. The action of these two forces in combination is known as the cohesion-tension theory, which is further supported by capillary action where the forces involved in cohesion cause the water molecule to adhere to the walls of xylem, thus pulling water up.

Translocation

Translocation primarily concerns the phloem vessels which have the following features:

- They're tubes made of living cells involved in translocation of nutrients to storage organs and growing parts of the plant.
- Consist of sieve tube elements and companion cells.
- Sieve tube elements form a tube to transport sugars such as sucrose, in the dissolved form of sap.
- Companion cells are involved in ATP production for active processes such as loading sucrose into sieve tubes.
- The cytoplasm of the sieve tube elements and companion cells is linked through structures known as plasmodesmata which are gaps between cell walls which allow communication and flow of substances such as minerals between the cells.

Translocation is an energy requiring process which serves as a means of transporting assimilates such as sucrose in the phloem between sources which release sucrose such as leaves and sinks e.g. roots and meristem which remove sucrose from the phloem.



The process of translocation occurs as follows:

1.Sucrose enters the phloem in a process known as **active loading** where companion cells use ATP to transport **hydrogen ions** into the surrounding tissue, thus creating a **diffusion gradient,** which causes the H+ ions to diffuse back into the companion cells.

2.**Facilitated diffusion** involving co-transporter proteins allows the returning H+ ions to bring sucrose molecules into the companion cells, thus causing the concentration of sucrose in the companion cells to increase.

3.As a result the sucrose diffuses out of the companion cells down the **concentration gradient** into the sieve tube elements through links known as **plasmodesmata**.

4. As sucrose enters the sieve tube elements, the **water potential** inside the tube is reduced, therefore causing water to enter via **osmosis** from the xylem, increasing the **hydrostatic pressure** of the sieve tube element.

5. As a result water moves down the sieve tube from an area of **high hydrostatic pressure** to an area of **low hydrostatic pressure**.

6. Eventually, sucrose is removed from the sieve tube elements by diffusion or active transport into the surrounding cells, thus increasing the water potential in the sieve tube. This in turn means that water leaves the sieve tube by **osmosis** back into the xylem, and as a result **reduces the pressure in the phloem at the sink.**

Therefore, in summary the mass flow of water from the source to the sink down the **hydrostatic pressure gradient** is a means of supplying assimilates such as sucrose to where they are needed.

<u>Evidence for and against mass transport</u>

For:

- There is **pressure in the sieve tube elements**, as shown by sap being released when the stem of a plant is cut.
- The **concentration of sucrose** is higher in the leaves (source) of plants than in roots (sink).
- **Increases in sucrose levels in the leaves** are followed by a similar **increase in sucrose concentration in the phloem**.
- Metabolic poisons/a lack of oxygen inhibit translocation of sucrose in the phloem.

Against:

- The function of the **sieve plates** is unclear as they would appear to **hinder mass flow** (some suggest though they have a structural function to help prevent bursting under pressure).
- Not all solutes move at the same speed, they should do if it is mass flow.
- Sucrose is delivered at more or less the same rate to all regions, rather than going more quickly to the ones with the lowest sucrose concentration, which the mass flow theory would suggest.

Ringing Experiments

In order to investigate if the phloem is responsible for mass flow a **ringing experiment** can be used. In this the bark and phloem of a tree are removed leaving just the **xylem** in the centre. Overtime the tissues above the missing ring **swell with sucrose solution** and the **tissue below dies**. This shows that sucrose is transported in the phloem.

Tracer Experiments

Tracer experiments can also be used to investigate the transport of sucrose in plants. Plants are grown in a environment that contains **radioactivity labelled carbon dioxide (14CO2)**. The presence of this means that they are incorporated into the sugar produced in photosynthesis.

The movement of these sugars can now be traced through the plant using **autoradiography**. Those areas that have been exposed to the radiation produced by the ^{14}C in the sugars will appear **black**. It follows that these regions correspond to the area where the phloem is and therefore suggest that this is where the sugars are transported.