

Topic 3 – organisms exchange substances with their environment

Key words

Ventilation – the movement of air in and out

Inspiration – the movement of air into the lungs

Expiration – the movement of air out of the lungs

Residual volume – the small volume of air that is left in the lungs even after forced expiration.

Tidal volume – the volume of exhaled air after normal inspiration

Forced expiratory volume (FEV) – the maximum volume of air a person can expel after maximum inhalation.

Counter current flow – the movement of water and blood flow in opposite directions.

Tissue fluid – is the fluid that surrounds tissues it consists of plasma, dissolved nutrients and oxygen (proteins and cells are too large to move out of the capillaries).

Translocation - is the movement of sucrose and amino acids in the phloem, from regions of production (the 'source') to regions of storage or to regions where they are used in respiration or growth (the 'sink').

Transpiration – the movement of water in the xylem from the roots to the leaves where it evaporates.

Cohesion-tension theory – how the water is pulled up from the roots to the leaves.

Mass flow hypothesis – the mechanism of movement of organic substances (like glucose) move around a plant through the phloem

- 1) The **smaller** organisms have a **large surface area to volume ratio**, so they do not need a gas exchange system, they rely of simple diffusion.
- 2) **Larger** organisms have a **small surface area to volume ratio**, so they need adaptations to facilitate gas exchange.
- 3) All gas exchange systems are adapted to allow **diffusion** they must have a:
 - a. Thin diffusion pathway
 - b. Large surface area
 - c. Large difference in concentration gradient.
- 4) Humans have a **trachea** branching into **bronchi** and then further into **bronchioles** and then into **alveoli**. Gas exchange takes place over the alveolar epithelium by diffusion.
 - a. **Thin** diffusion pathway - Alveoli a one cell thick (the epithelium) and the capillary wall is also one cell thick, so oxygen and carbon dioxide have a thin diffusion pathway
 - b. **Large surface area** – there are lots of alveoli surrounded by a network of capillaries.
 - c. **Large difference in concentration gradient** – this is created by the constant movement of blood flow and the ventilation of gases in the lungs.
- 5) **Ventilation** - There is surfactant (liquid around the lungs) to reduce surface tension during ventilation.
 - a. **Inspiration**
 - i. External intercostal muscles contract
 - ii. Internal intercostal muscles relax

- iii. The diaphragm contracts and flattens
- iv. This increases the volume of the thorax
- v. This decreases the pressure inside the lungs
- vi. Air moves from higher pressure outside of the lungs to lower pressure inside the lungs

b. Expiration

- i. External intercostal muscles relax
- ii. Internal intercostal muscles relax
- iii. The diaphragm relaxes and arches
- iv. This decreases the volume of the thorax
- v. This increases the pressure inside the lungs
- vi. Air moves from higher pressure inside of the lungs to lower pressure outside the lungs

c. Forced expiration, the same as expiration but **Internal intercostal** muscles contract.

- 6) Pulmonary ventilation ($\text{dm}^3\text{min}^{-1}$) = tidal volume (dm^3) x ventilation rate (min^{-1})
- 7) **Pulmonary tuberculosis** is a bacterial infection that causes inflammation and damages tissue leaving scar tissue behind.
- 8) **Pulmonary fibrosis** is caused by cigarette smoke. This causes the epithelium to become thickened- called fibrosis. This means oxygen will not diffuse as well into the blood. Fibrosis also reduces the elasticity therefore decreasing ventilation.
- 9) **Asthma** is an allergic reaction caused by the reaction to an allergen (pollen, dust etc.). This causes the bronchioles and bronchi to become inflamed and the epithelia cells to secrete mucus. This constricts the airways.
- 10) **Emphysema** is caused by smoking. Elastin in the alveoli is damaged. This reduces the surface area for diffusion.
- 11) Insects have a **tracheal** system – **spiracles** on the outer surface branching into **tracheoles** and then further branching into **tracheae**.
- 12) Insects also have a **waterproof** coating and open and close their **spiracles** to prevent water loss.
- 13) **Fish** have gills – gill arches have gill **lamellae** branching off with lots of **filaments**.
 - a. Fish also have use a **counter current flow**. Blood flows the opposite direction to the flow of water, this insures that the concentration gradient for diffusion of oxygen and carbon dioxide is maintained along the entire length of the gill lamellae.
- 14) **Leaves** have a spongy **mesophyll** layer to allow gasses to move around the cells and stomata to allow gases to move in and out of the leaf.
- 15) **Xerophytic** plants are adapted to cope with low water conditions
 - a. **Sunken stomata** – to increase the humidity around the stomata to decrease the concentration gradient
 - b. **Hairs** – to trap water next to the surface to decrease the concentration gradient
 - c. **Rolled up leaves** - to trap water next to the surface to decrease the concentration gradient
 - d. **Thick waxy surface** – to increase diffusion pathway
 - e. **Small leaves/spines** – to reduce surface area for evaporation
- 16) During **digestion** large molecules are hydrolysed to form smaller molecules that can be absorbed across cell membranes,
- 17) Starch and glycogen are hydrolysed into disaccharides by **amylase**
- 18) Membrane bound **disaccharidases** hydrolyse disaccharides into monosaccharides
 - a. Membrane bond enzymes mean that the molecules are hydrolyses into small soluble molecules next to the absorption surface to allow for more efficient absorption.

- 19) **Maltase** hydrolyses maltose into 2 glucose molecules
- 20) **Surcease** hydrolyses sucrose into glucose and fructose
- 21) **Lactase** hydrolyses lactose into glucose and galactose
- 22) Lipid droplets are emulsified into **micelles** by the addition of **bile** salts – this increases the surface area lipase enzymes to function
 - a. Bile salts are made in the liver and stored in the gall bladder.
- 23) Lipids are hydrolysed into 3 fatty acids and glycerol by **lipase**.
- 24) Proteins are hydrolyses into amino acids.
 - a. **Endopeptidases** – act on internal bonds of a proteins
 - b. **Exopeptidases** – acts on terminal bonds
 - c. **Membrane- bound dipeptidases** – hydrolyse dipeptides
- 25) The movement of **glucose** (and amino acids) is by co-transport in the lining of the ileum (small intestine).
 - a. There are 3 proteins involved
 - i. **Na⁺/glucose transporter** – this co-transporter moves glucose and Na⁺ from the lumen (inside) of the small intestine into the epithelial cell.
 - ii. **Glucose channel proteins** – Glucose then moves by facilitated diffusion from the epithelial cell into the capillary
 - iii. **Na⁺/K⁺ co-transporter** – to maintain the Na⁺ gradient (high concentration in the ilium and low concentration in the epithelial cell) Na⁺ is removed from the cell by the Na⁺/ K⁺ pump but in exchange K⁺ moves into the epithelial cells.
- 26) **Haemoglobin** is a globular protein with a quaternary structure.
- 27) Haemoglobin is found in red blood cells and has 4 Fe²⁺
- 28) The haemoglobin dissociation curve is a curve because of **co-operative binding**. It Is hard to bind the first O₂ then is easier to bind the next 2 O₂ and then harder to bind the 4th O₂.
- 29) At the lungs there is a high PP O₂ (PP – Partial pressure) so there is **loading** of oxygen into haemoglobin
- 30) At the tissues there is a low PP O₂ (because O₂ has been used for aerobic respiration) so there is **unloading** at the tissues.
- 31) If there is lots of carbon dioxide present at the tissues because of increase aerobic respiration the oxygen dissociation curve will shift to the right. This is because the increased carbon dioxide increases the acidity. More O₂ will unload at the tissues at the same PP O₂. This will allow for more aerobic respiration – This is called the **Bohr effect**.
- 32) **In low O₂** environments (high altitudes, bottom of a pond, foetus etc.) the curve will shift to the right. This will affect the loading of O₂ at the lungs. More O₂ with load a lower PP O₂ meaning more O₂ is then able to enter the blood stream for aerobic respiration.
- 33) In organisms that have a **fast metabolism** the oxygen dissociation curve will always be further to the right to allow more unlading at the tissues.
- 34) The **heart** has two **atria** (the compartments at the top) and two ventricles (the compartments at the bottom) – remember the left and the right side are labelled as if the heart was on you.
- 35) The **aorta** leaves the left ventricle to take oxygenated blood to the rest of the body.
- 36) The **vena cava** returns deoxygenated blood into the right atrium.
- 37) The **pulmonary artery** takes deoxygenated blood from the right ventricle to the lungs.
- 38) Then **pulmonary vein** brigs oxygenated blood from the lungs into the left atrium.
- 39) Between the atrium and the ventricles are called **atrioventricular valves**.
- 40) Between the ventricles and aorta/pulmonary artery are **semi-lunar valves**

- 41) The valves open and close with pressure change to maintain **unidirectional** flow
- As the atria contract high pressure will be created causing the A-V valve to open
 - As the ventricle contracts high pressure will be created causing the A-V to close and the semi-lunar valve to open.
- 42) **Arteries** – carry blood away from the heart at high pressure
- Have a thick muscular wall
 - Lots of elastic fibres
 - Thick outer layer of smooth muscle
 - Relatively small lumen
- 43) **Arterioles** – are smaller arteries
- 44) **Capillaries** – small blood vessels that link arterioles to venules
- Endothelium is just one cell thick
 - Small lumen – just enough for one cell to fit at a time this slows down blood flow to give more time for gas exchange
- 45) **Venules** – smaller veins
- 46) **Veins** – return blood back to the heart
- Large lumen
 - Thinner layer of smooth outer muscle
 - Valves to prevent backflow
- 47) All blood vessels have a smooth inner surface called the **endothelium**.
- 48) **Tissue fluid** is formed when high **hydrostatic** pressure is created at the arteriole end of the capillaries. This forces fluid out into the tissues. This consists of plasma, dissolved nutrients and oxygen (proteins and cells are too large to move out of the capillaries).
- 49) Inside the capillaries there will be a lower water potential because all the fluid has been forced out. This means that water moves back into the capillary at the venule end by **osmosis**.
- 50) Not all fluid is returned to the capillary, excess fluid is removed by the **lymph** system.
- 51) **Xylem** transports water from the roots to the leaves of a plant this is called **transpiration**
- They are dead so water does not leave because the cells do not affect the water potential.
 - Water moves up the xylem in one continuous column. This is because to the **cohesion tension theory**.
 - Water evaporated out of the stomata this causes negative pressure at the top of the water column in the xylem – this creates tension so the next water molecule will move up.
 - Water molecules are polar so they are adhesive to the walls of the xylem and they are cohesive to each of the molecules so the water molecules because of intermolecular forces move up in one continuous stream.
 - Evidence for the cohesion tension theory
 - The diameter of the vessel shrinks when transpiration is at its highest – this is because of the greater tension created by the increased evaporation.
 - When a xylem vessel is broken no water can be pulled up and air moves up instead because the continuous stream has been broken.
- 52) **Phloem** transports organic substances such as glucose around the plant, from source cells – where the substances are made/taken in to sink cells – where substances are stored or used for growth/respiration this is called translocation

53) **Phloem** are made up of living cells they have a companion cell with plasmodesmata (gaps that allow transfer of substances) into the hollow sieve tube, at the end of each sieve tube is a sieve plate.

54) Substances are moved in the phloem by the **mass flow hypothesis**:

- a. At source cells – glucose is loaded by facilitated diffusion or active transport into the sieve tube through the companion cell.
- b. This lowers the water potential inside the sieve tube
- c. Water moves by osmosis from xylem into the sieve tube – this creates high pressure.
- d. At sink cells the glucose will be moved out of the sieve tube by facilitated diffusion.
- e. This will increase the water potential inside the sieve tube.
- f. This causes the water potential to be higher in the sieve tube than the water potential in the xylem – so water moves back in by osmosis.
- g. This creates a lower pressure at the sink cells.
- h. The net movement in the sieve tube is because of the difference in pressure. The movement from high pressure in sieve tube to low pressure.

55) **Experiment** have been carried out to show translocation

- a. Radioactive tracers have been used to observe the movement of carbon (and therefore glucose) within a plant.
- b. Sections of phloem have been cut away from tree trunks. Glucose has been shown to collect above the cut phloem but is unable to move below the cut section. This is called a ringing experiment.