

AS Biology – Revision Notes
Unit 3 – Physiology And Transport

The Heart And Circulation

1. Multicellular organisms cannot rely on their surface area to get oxygen and nutrients to all the cells. Instead they have a specialised circulatory system.
2. Double circulation gives a more efficient supply of oxygen to the cells – as one lot of red blood cells are dropping off O₂, another lot is becoming more oxygenated. The two systems are:
 - a. Pulmonary – from the heart to the lungs and back.
 - b. Systemic – from the heart to the rest of the body and back.
3. The cardiac cycle takes place as follows:
 - a. Atria receive blood.
 - b. Auriculoventricular valves (bicuspid and tricuspid) open.
 - c. Auricular systole – atria contract, forcing blood into ventricles.
 - d. Ventricular systole – ventricles contract, forcing blood through the semilunar valves into the aorta and pulmonary artery.
 - e. Auricular and ventricular diastole – all chambers relax.
4. Cardiac muscle cells beat autonomously. Groups of cells beat in a coordinated manner. The heart beat is myogenic (originating in the heart), as opposed to neurogenic (originating outside the heart).
5. The cardiac cycle is controlled by electrical impulses:
 - a. The electrical impulse originates at the sino-atrial node (SAN). This stimulates atrial systole (lasts about 0.1s).
 - b. The electrical impulse reaches the atrio-ventricular node (AVN), then travels down the bundle of His and along the Purkinje fibres to the base of the ventricles. This stimulates ventricular systole (lasts about 0.3s).
 - c. The impulse ends, and diastole takes place (lasts about 0.4s).
6. In an electrocardiogram (ECG), the electrical activity is shown by peaks. The small P wave shows the contraction of atrial muscles. The very large R wave shows the contraction of ventricle muscles. The T wave shows the relaxation of ventricle muscles.
7. The pressures in the heart change during the cardiac cycle:
 - a. The atria passively fill with blood from the pulmonary vein and vena cava, and so the pressure increases.
 - b. As the atrial systole takes place, the pressure increases and the blood is forced into the ventricles causing the pressure there to increase.
 - c. As the AV valves close, the atrial pressures drop.
 - d. As the ventricular systole takes place, the pressure increases dramatically in the ventricles. The semilunar valves open and also increase the pressure in the aorta.
 - e. As the diastole takes place, the pressure in the ventricles drops again. The semilunar valves close, and the AV valves open again.
 - f. The pressure in the aorta increases after the semilunar valves close, but then decreases as the blood is passed into other arteries.
8. The chordae tendinae cause the AV valves to close by snapping back, to stop any more blood flowing through.
9. Blood pressure can be measured using a sphygmomanometer.
10. There are three types of muscle in the body:
 - a. Cardiac muscle – This consists of strips of muscle fibres, with the cells separated by intercalated discs. These fibres are linked together in many cross-linkages.
 - b. Skeletal muscle – This is responsible for voluntary movement. The cells are arranged into filaments, containing strips of actinomyosin.
 - c. Smooth muscle – This is responsible for the movement of substances along ‘tubes’, usually by peristalsis.
11. The aorta acts as a blood reservoir (the walls stretch) during the systole, and as a subsidiary pump (a bit like peristalsis) during the diastole.
12. As arteries divide into arterioles and then capillaries, the cross-sectional area of the blood vessels increases. Therefore the pressure decreases because there is a greater area to spread it out.
13. Arteries, arterioles, venules and veins all have the following structure (from the outside inwards):
 - a. Loose connective tissue.
 - b. Elastic fibres and smooth muscle.
 - c. Elastic internal membrane.

- d. Endothelium.
 - e. Lumen (space within blood vessel).
14. Arteries have the following features:
 - a. Rich in elastic fibres so can stretch.
 - b. Tough and thick walls to withstand pressure.
 - c. Arterioles are very muscular, so can constrict or dilate to control blood flow.
 15. Veins have the following features:
 - a. Relatively thin walls, as blood is at a low pressure.
 - b. Contains valves to prevent the backflow of blood.
 16. Blood is kept moving through the veins due to:
 - a. The small residual pressure of blood from the capillaries.
 - b. The reduced pressure in the atria during diastole.
 - c. Leg muscles act as a secondary heart to contract and force blood upwards.
 17. Capillaries consist of a single layer of endothelial cells. They are therefore thin and permeable to allow rapid diffusion and exchange.
 18. There are five main fluids in the body:
 - a. Blood – complex fluid in blood vessels.
 - b. Plasma – fluid component of blood.
 - c. Lymph – fluid in lymph vessels (plasma and lipids).
 - d. Tissue fluid – fluid surrounding living cells (plasma without proteins).
 - e. Serum – used for treating burns (plasma without fibrinogen).
 19. There are four main components of blood:
 - a. Red blood cells – biconcave enucleated cells containing haemoglobin.
 - b. White blood cells – involved in the immune system.
 - c. Platelets – involved in blood clotting.
 - d. Plasma – water, dissolved salts and plasma proteins. The plasma proteins are enzymes, fibrinogen (for blood clotting), globulins (for the immune system) and albumins (to maintain the osmotic potential of the blood).
 20. Water is exchanged between the blood and the tissue fluid due to two forces:
 - a. Hydrostatic pressure – pressure due to the heart tends to push water out of the capillaries. This occurs at the arterial end of the capillaries
 - b. Water potential – low water potential in capillaries due to plasma proteins draws water into the vessels. This occurs at the venous end of the capillaries.
 21. Small lymph vessels are located near to the capillaries and body cells. The lymphatic system is the drainage system of the body, and keeps tissue fluid consistent. There are lymph nodes at various places in the body, and these filter the lymph, and also produce lymphocytes. Lymph re-enters the blood just beneath the right subclavian vein.
 22. Oxygen is carried in the red blood cells as oxyhaemoglobin – $\text{Hb} + 4\text{O}_2 \rightleftharpoons \text{HbO}_8$.
 23. The oxygen dissociation curve illustrates the way in which oxygen is exchanged:
 - a. It is an s-shaped curve.
 - b. For a high partial pressure of oxygen in the lungs, the haemoglobin becomes fully saturated quickly (the curve is level at this point).
 - c. For a low partial pressure of oxygen in the tissues, the oxyhaemoglobin dissociates and releases much of its oxygen (the curve is steep at this point). A small drop in the pp of oxygen can cause a relatively large drop in the saturation of haemoglobin, causing large amounts of oxygen to be released.
 - d. It allows a quick pickup of oxygen at high pp, and quick drop off of oxygen at low pp.
 24. The curve for foetal haemoglobin is to the left of haemoglobin, as it has a higher affinity for oxygen than adult haemoglobin, so it will pick up oxygen when the adult haemoglobin releases it.
 25. The curve for myoglobin is to the left of haemoglobin, as it is found in muscle cells, and so has a high affinity for oxygen and can therefore pick it up more easily, and drop it off less easily, acting as an oxygen store.
 26. The Bohr effect states that when the blood is high in CO_2 , the curve is shifted to the right, reducing the affinity of the haemoglobin for oxygen. So in metabolically active cells, the harder they work the more carbon dioxide is released, and so the more oxygen is released by haemoglobin.
 27. Carbon dioxide is transported in the blood:
 - a. CO_2 diffuses out of respiring cells into the red blood cell.
 - b. Carbonic anhydrase catalyses the production of carbonic acid, which then dissociates into H^+ and HCO_3^- ions – $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$.

- c. The H^+ ions combine with haemoglobin, releasing $O_2 - HbO_8 + H^+ \rightleftharpoons HHb + 4O_2$. This helps to keep the blood pH constant, by 'mopping up' excess H^+ ions.
 - d. The O_2 molecules diffuse into the respiring cells.
 - e. The HCO_3^- ions diffuse into the plasma, and Cl^- ions flow into the red blood cell to conserve the ionic balance of the blood. This is the chloride shift.
28. In the lungs, the reverse of these reactions occur, causing CO_2 to be released.

Control Of Heartbeat And Breathing

1. Parts of the body not under conscious control are controlled by the autonomic nervous system:
 - a. Sympathetic nerves generally speed things up.
 - b. Parasympathetic nerves generally slow things down (the origin is the vagus nerve).
2. The medulla oblongata is located in the hindbrain, and is responsible for controlling the heart rate and the breathing rate.
3. The cardiovascular centre in the MO is responsible for the control of heartbeat:
 - a. The cardioacceleratory centre will speed up the heartbeat.
 - b. The cardioinhibitory centre will slow down the heartbeat.
4. To speed up the heartbeat:
 - a. Impulses from the cardioacceleratory centre are sent to the SAN.
 - b. The hormone noradrenaline is released.
 - c. Noradrenaline increases the rate of impulse production by the SAN.
 - d. This causes an increase in the rate of heartbeats and the strength of contractions.
5. To slow down the heartbeat:
 - a. Impulses from the cardioinhibitory centre pass down the vagus nerve to both the SAN and AVN.
 - b. Acetylcholine is released in the SAN and AVN.
 - c. This inhibits the production of impulses by the SAN and the transmission of impulses.
 - d. The heartbeat is slowed down and the strength of each contraction is reduced.
6. Chemoreceptors in the MO (central receptors) and at the aortic sinus and carotid sinus (peripheral receptors) detect the level of CO_2 in the blood. These send impulses to the cardioacceleratory centre, to therefore increase the heartbeat.
7. There are also pressure receptors in the aortic and carotid sinuses:
 - a. For an increase in blood pressure, the cardioinhibitory centre is stimulated and the cardioacceleratory centre is inhibited. Also, impulses are sent to the vasomotor centre in the MO, which sends impulses to arterioles to cause vasodilation.
 - b. For a decrease in blood pressure, the MO sends impulses via the sympathetic nervous system to the heart (increase rate and strength of contractions), and to the arterioles to cause vasoconstriction.
8. There are three centres in the respiratory centre of the MO, which is responsible for the control of breathing:
 - a. Inspiratory centre – causes inspiratory muscles (intercostals and diaphragm) to contract.
 - b. Expiratory centre – shuts down the inspiratory centre by negative feedback.
 - c. Pneumotaxis centre – controls the other two centres (located in the pons).
9. The sequence of ventilation:
 - a. The inspiratory centre sends impulses to the diaphragm and external intercostal muscles, causing them to contract. Air is forced into the lungs due to the pressure change.
 - b. Stretch receptor cells in the bronchioles are stimulated as the lungs inflate (and stretch), and send impulses to the expiratory centre of the brain.
 - c. The expiratory centre sends impulses to inhibit the inspiratory centre (negative feedback).
 - d. Impulses to the muscles are inhibited, so inspiration stops, the muscles relax, and expiration takes place.
10. Chemoreceptors detect an increase in the level of CO_2 in the blood, as for the control of heartbeat. These will send impulses to the inspiratory centre and the ventral group in the MO, which cause the diaphragm and external intercostal muscles to contract, and the rate and depth of breathing to increase.
11. Higher parts of the brain (e.g. the cerebral cortex) can override the normal rate of breathing.

Energy And Exercise

1. There are three main energy sources in the body:
 - a. Glucose – in the blood.
 - b. Glycogen – in the liver and muscles.

- c. Triglycerides – in adipose tissue under the skin (for peak energy demands).
2. The level of glucose in the blood is controlled by the liver:
 - a. Glucose from the small intestine enters the liver.
 - b. Glycogen and glucose are interconverted to maintain a constant blood glucose level.
 - c. Excess glucose is converted into triglycerides. Excess triglycerides are transported to fat stores in the body.
3. The interconversion of glucose and glycogen is controlled by hormones:
 - a. Glucagon stimulates phosphatase enzymes in the liver to convert glycogen to glucose.
 - b. Insulin stimulates the cells to take up glucose from the blood.
4. Respiration takes place in a number of stages:
 - a. In the cytoplasm – glycolysis takes place to convert glucose into pyruvate.
 - b. In the mitochondria – the Krebs cycle and terminal oxidation take place to convert pyruvate into CO_2 , H_2O , and ATP.
5. The overall equation for respiration is $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2 + 36\text{ATP}$.
6. For the production of ATP – $\text{ADP} + \text{P}_i \rightleftharpoons \text{ATP}$.
7. Without the presence of oxygen, anaerobic respiration takes place:
 - a. In plants, this is fermentation, and ethanol is produced ($\text{C}_2\text{H}_5\text{OH}$).
 - b. In muscles, lactic acid is produced ($\text{C}_3\text{H}_6\text{O}_3$) – $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_3\text{H}_6\text{O}_3 + 2\text{ATP}$.
8. Lactic acid inhibits muscle action by dissociating into H^+ and lactate:
 - a. H^+ ions lower the pH in muscle cells.
 - b. This gives the wrong pH for enzymes, so glycolysis slows down.
 - c. H^+ ions interfere with muscle contractions causing stiffness.
9. Lactate needs to be converted into pyruvate again by aerobic respiration, and the heart and liver are very good at doing this quickly.
10. At the start of a period of exercise, anaerobic respiration takes place, whilst the level oxygen builds up for aerobic respiration to take place. This lack of oxygen to begin with is the oxygen deficit, and must be taken up at the end of the exercise period to oxidise all the lactate that was produced. This is the oxygen debt.
11. For short periods of exercise, the person doesn't have long to breathe, and so most of the respiration will be anaerobic. For longer periods of exercise, more of the respiration taking place will be aerobic.

Transport In Plants

1. The primary root of a dicotyledonous plant has a central vascular bundle, surrounded by the endodermis, the cortex and then the epidermis. The vascular bundle contains xylem tissue (in an x-shape) surrounded by four bundles of phloem tissue. These are separated by the cambium.
2. A young stem contains separate vascular bundles, arranged towards the edge of the cortex. The xylem vessels will be on the outside of the vascular bundles, with the phloem vessels inwards.
3. The growing point for a plant is the meristem, just behind the root tip. Behind this is a region of elongation, followed by a region of differentiation (where cell differentiation takes place).
4. The root tip and meristem is protected by a root cap – made of cells embedded in mucus.
5. Water is taken into the plant through the roots by osmosis:
 - a. Root hair cells provide a large surface area for osmosis.
 - b. Water surrounding soil particles moves through the root hair cells and the cortex, down a water potential gradient. This is the symplast pathway (through the cell cytoplasm).
 - c. Plasmodesmata are small strands of cytoplasm through the cell walls, creating a continuous network of cytoplasm. The water in the symplast pathway can therefore move continuously.
 - d. Water can also pass through the cellulose fibres in the cell walls of the epidermis and cortex. This is the apoplast pathway (and is also continuous).
 - e. The endodermis contains the Casparian strip (a waterproof layer), which blocks the apoplast pathway. To enter the xylem vessels, water must pass through the endodermis by the symplast pathway – the amount of water entering the xylem vessels can be controlled.
6. Xylem vessels consist of dead cells, which are joined together to form a continuous tube with the cell contents flushed out. The walls contain lignin, which is impervious to water.
7. Water is moved up the xylem vessels to the leaves:
 - a. Evaporation from the leaves creates suction – air has a very low water potential, so water will evaporate from the surface of the mesophyll into the air. This creates a suction effect, to pull the water up the xylem vessels.

- b. Root pressure – water is continuously taken in by the roots and ‘pushed’ up the xylem.
 - c. Capillary action – the xylem vessels are very thin, and so attract water upwards.
8. The cohesion-tension mechanism explains how water is moved up the xylem:
 - a. For the tallest trees, the weight of the column of water would be expected to cause the column to break, but this doesn’t happen.
 - b. The water molecules ‘stick’ together due to hydrogen bonding, causing the water to stay together as a column.
 - c. The water column is strongly attracted to the walls of the xylem vessels, so as water is evaporated from the leaves, the column becomes smaller, causing the xylem vessels to become thinner.
9. During the day, the circumference of a tree-trunk will decrease, as more water is lost than is taken in (and so xylem vessels become thinner due to cohesive-tension). At night, more water is taken in than is lost, so the circumference of the tree-trunk will increase as the xylem vessels swell.
10. Mineral salts are absorbed by the roots in two main mechanisms:
 - a. Actively – ions are absorbed against a concentration gradient by active transport.
 - b. Passively – ions move with the water through the apoplast pathway.
 - c. Endodermal cells must actively secrete mineral ions into the xylem vessels.
11. Minerals absorbed by the plant have various uses:
 - a. Nitrate ions (NO_3^-) – synthesis of amino acids and nucleic acids.
 - b. Phosphate ions (PO_4^-) – synthesis of ATP, DNA and some proteins.
 - c. Magnesium ions (Mg^{2+}) – synthesis of chlorophyll.
12. Transpiration is the loss of water from the upper surfaces of a plant by evaporation.
13. The transpiration stream is the continuous flow of water through the plant from the roots to the leaves.
14. The rate of transpiration is affected by:
 - a. Temperature – the hotter it is, the more water evaporates.
 - b. Humidity – the more saturated the air, the less evaporation can take place (higher ψ).
 - c. Wind speed – water molecules are ‘blown’ away to give a higher diffusion gradient.
 - d. Light – during photosynthesis (in the light), stomata will be open so more water will evaporate (except for cacti).
15. A potometer can be used to measure the rate of transpiration:
 - a. It is always set up underwater, and time is allowed for the system to settle.
 - b. The bottom of the stem is cut underwater to remove air in xylem vessels.
 - c. An air bubble is introduced to the capillary tube, and the movement is measured.
 - d. A water reservoir is used to reset the air bubble.
16. Stomata can open and close to allow air into and out of the spaces in the mesophyll:
 - a. The guard cells have a much thicker inner wall than the outer wall, and have cellulose microfibrils across the diameter of the stoma.
 - b. When the guard cells take in water, they cannot become fatter as the microfibrils won’t stretch. The cells become stretched along the outer walls, and therefore become more c-shaped, so the stoma will open.
 - c. Potassium ions (K^+) are actively secreted into and out of the guard cells.
 - d. When K^+ ions are pumped into the guard cells from neighbouring cells, the ψ decreases, so water moves into the guard cells and the stoma will open. K^+ ions are secreted back into the neighbouring cells by the guard cells in order to close the stoma.
 - e. The secretion of K^+ ions is controlled by the hormone abscisic acid (ABA), which is produced in times of water stress and causes the guard cells to rapidly secrete K^+ ions.
17. Synthesised foods are moved through a plant in the phloem tissues. These are living enucleate cells, with sieve plates between them through which the cytoplasm is continuous. Each sieve tube element has a companion cell, which has a dense cytoplasm and many mitochondria to control the sieve tube elements, and provide the ATP needed for active transport.
18. Transport in the phloem is called translocation, and works on the mass flow hypothesis:
 - a. Carbohydrates are moved through the phloem tissue as sucrose.
 - b. The source contains a high concentration of sucrose, and will be either mature leaves (where sucrose is produced from photosynthesis) or the roots (where sucrose is released from the stores of starch when needed).
 - c. The sink contains a low concentration of sucrose and will either be the roots (where sucrose is stored as starch) or the growing points, i.e. new leaves (where sucrose is respired to provide ATP for growth).

- d. Sucrose is actively transported into the phloem at the source, creating a high hydrostatic pressure, and the sucrose diffuses out of the phloem at the sink, creating a low hydrostatic pressure. The water will move from the high to the low hydrostatic pressure (i.e. from source to sink), transferring the dissolved sucrose with it.
19. Malpighi's experiment demonstrated the presence of phloem vessels:
- A ring of bark (containing phloem but not xylem) was removed from the stem (i.e. a 'ringing' experiment was used).
 - After a few weeks, swelling appeared above the ring, showing that substances were moving down the phloem vessels from the leaves.
 - In the winter, no such swelling occurred, because there were no leaves as the source.
20. Chen's experiment demonstrated the movement of sucrose through the phloem vessels:
- A particular leaf was given radioactive carbon dioxide ($^{14}\text{CO}_2$).
 - Autoradiography was used to show where the radioactive sucrose moved, and eventually accumulated (in the growing points, or in the roots).
21. Aphids can be used to tap into a phloem vessel – a feeding aphid is removed so that only the mouthpiece (stylet) is left in place, and the phloem coming out of this can be collected. The fluid in phloem vessels contains mainly sucrose with some amino acids and proteins.
22. A xerophyte is a plant that can live in dry situations, and is adapted to reduce water loss.
23. Marram grass (grows in sand dunes):
- The leaves are tubular, and roll up to create a small space within the leaves that quickly becomes saturated – humid air is trapped around the leaf surface.
 - The outer surface of the leaf has a thick cuticle.
 - The inner surface of the leaf has small hairs, creating 'still air' next to the stomata.
24. Tortula (a moss that grows in sand dunes):
- The leaves wrap around the stem to reduce the surface area, and reduce water loss.
 - During rainfall the leaves open out so more photosynthesis can take place.
25. Desert plants need to be adapted to:
- Get the water that they need – widespread shallow root systems get as much dew as possible, whereas very deep root structures get water far under the ground.
 - Preserve the water they have – in drought the leaves are lost to stop transpiration. During rainfall, the leaves quickly regrow to replenish food stores.
26. Cacti (grow in deserts):
- The leaves are reduced to spines to reduce the surface area and loss by transpiration (the spines also act as protection).
 - The stem is swollen, giving a low surface area to volume ratio and acting as a water reservoir.
 - The stem has a thick waxy cuticle to prevent water loss.
 - The stomata are located on the stem, so photosynthesis doesn't stop.
 - The stomata are sunken, and surrounded by hairs, to trap the humid air around them and prevent transpiration.
27. Some desert plants (e.g. cacti) use crassulacean acid metabolism (CAM):
- The stomata only open at night (to reduce transpiration), so there is no light for normal photosynthesis.
 - CO_2 is absorbed at night to make malic acid – organic compound + $\text{CO}_2 \rightleftharpoons$ malic acid.
 - Malic acid is stored in the vacuoles, and used in metabolism during daylight to give the CO_2 for photosynthesis (uses a C-4 pathway).