9.2 - Maintaining a Balance:

1. Most organisms are active within a limited temperature range:

- *Identify the role of enzymes in metabolism, describe their chemical composition and use a simple model to describe their specificity in substrates:*
  - Role of enzymes in metabolism:
    - Metabolism refers to all the chemical reactions occurring in organisms
    - Enzymes are biological catalysts which increase the rate of chemical reactions
    - Without enzymes, metabolism would be too slow to support life
  - Chemical composition of enzymes:
    - All enzymes are made of protein
    - Proteins consist of one or more polypeptide chain.
    - These are composed of long chains of amino acids joined together by peptide bonds
  - Structure of enzymes:
    - In enzymes, the polypeptide chain is folded into a 3-dimensional globular shape
    - Part of the enzyme is called the active site. This part attaches to the substrate
    - The substrate are the molecules the enzymes acts upon
  - Specificity of enzymes:
    - Enzymes are highly specific in their action; this means that each enzyme acts on one substrate only
    - This is because the shape of the active site of the enzyme matches the shape of the substrate material
    - The molecules the enzyme act upon are called the substrate
    - The substrate molecules bind to the active site and a chemical reaction occurs
    - The products are the substances that the substrate(s) become. One substrate can be split, or two substrates can be joined
  - Models to explain specificity:

- The Lock and Key Model suggests that the substrate fits exactly into the active site of the enzyme like a key fits into a lock. It assumes that the enzyme had a rigid and unchanging shape.
- The Induced Fit Model states that the binding of the substrate to the enzyme 'induces' a temporary change in shape of the enzyme. The new shape of the enzyme better accommodates the shape of the substrate and a reaction occurs.

- *Identify the pH as a way of describing the acidity of a substance:*
  - The substance that makes a solution acidic is hydrogen ions
  - pH is a measure of the acidity or the alkalinity of a substance
  - pH is a measure of the concentration of hydrogen ions per litre of solution
  - The pH scale is from 0 to 14: a pH of 7 is neutral (pure water); above 7 is alkaline and below 7 is acidic
- *Identify the effect of increased temperature, change in pH and change in substrate concentrations on the activity of enzymes:*
  - Enzyme function is affected by many factors, including:
    - Temperature:
      - Sensitivity to temperature relates to the protein structure of enzymes
      - As temperature increases, enzyme activity increases, up to the optimum temperature
      - This is because the enzyme and substrate molecules are moving faster (more kinetic energy) and therefore more collisions between enzyme and substrate occur
      - At high temperatures, the shape of the enzyme changes, and some of the enzymes can no longer accommodate the substrate. Activity decreases. However, if the temperature cools down, activity will start again
      - At VERY high temperatures, the enzyme is **denatured**; i.e. the chemical bonds holding the protein molecule together are broken and the shape is permanently changed. The enzyme is destroyed, can no longer accommodate the substrate, and will remain inactive even if the temperature returns to the optimum

- pH:
  - Enzymes work best at an optimum pH
  - This is usually within a very narrow range
  - Extremes of acidity or alkalinity can affect the bonds holding the 3D globular shape of the enzyme, denaturing the enzyme.
- Substrate concentration:
  - An increase in substrate concentration will increase the reaction until all enzyme active sites are occupied. Then the reactions will proceed at a maximum rate.

- *Explain why the maintenance of a constant internal environment is important for optimal metabolic efficiency:*
  - Enzymes are essential for proper metabolic function in an organism
  - However, enzyme efficiency is affected greatly by certain factors
  - These include **temperature**, **pH** and **substrate** concentration:
  - Enzymes work best within a limited range of environmental conditions
  - Therefore, a constant and stable internal environment is needed so that enzymes will always be working at an optimum rate, and thus metabolism will be a optimum efficiency
- *Describe homeostasis as the process by which organisms maintain a relatively stable internal environment:*
  - DEFINITION: Homeostasis is the process by which organisms maintain a relatively stable internal environment
  - The internal environment of cells are kept within certain limits by the coordinating systems of the body
  - These systems monitor all the activities of cells, their requirements and the wastes they produce – this is to maintain health.
  - This is called homeostasis.
- *Explain that homeostasis consists of two stages*
  - *Detecting changes from the stable state;*
  - *Counteracting changes from the stable state:*

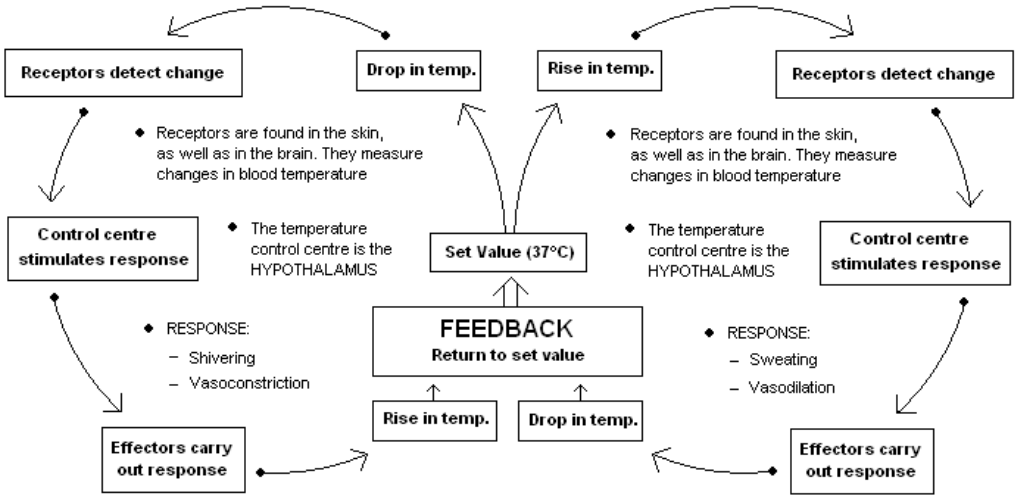
- Detecting Changes:
  - The body needs to maintain a 'stable state' in order to function properly
  - Changes, or deviations, from the stable state are caused by the external and internal environment
  - Any change, or information, that provokes a response is called a STIMULUS
  - RECEPTORS detect stimuli; organisms then react to the change
  - Examples of external stimuli: light, day length, sound, temperature, odours
  - Examples of internal stimuli: levels of CO_2, oxygen levels, water, wastes, etc.
  - Receptors can range from a patch of sensitive cells, to complex organs like the eyes and ears of mammals
- Counteracting Changes:
  - After receptors detect changes, organisms can then react to the change
  - This type of response will counteract the change to ensure the stable state is maintained
  - EFFECTORS bring about responses to stimuli
  - Effectors can either be muscles or glands:
    - Muscles bring about change by movement
    - Glands bring about change by secreting chemical substances

- *Gather, process and analyse information from secondary sources and use available evidence to develop a model of a feedback mechanism:*
  - *Homeostasis* involves the detection of the change in the environment and the response to that change
  - The *mechanism* that brings about this change is called FEEDBACK
  - In feedback systems, the response alters the stimulus
  - In living organisms, the feedback system has 3 main parts:
    - Receptors: A type of sensor that constantly monitors the internal environment
    - Control Centre: Receives info from the receptors and determines the response
    - Effector: Restores the set value. Keeps environments stable.
  - An example of a feedback system would be the control of body temperature
  - These receptors send their information to the control centre
  - The temperature control centre in mammals is the *hypothalamus*

- The hypothalamus responds by initiating responses to increase or decrease temperature, until it goes back to the set value (which is 37ºC)
- Temperature control responses:

Keeping Warm	Keeping Cool
Shiver to generate heat	Sweating; evaporation loses heat
Hair muscles erect; insulation	Blood vessels dilate; increased blood supple, more heat lost
Increased appetite	Hair relaxes, less insulation
Blood vessels constrict; less blood flow, less heat loss	Decrease in metabolism
Increase in metabolism	Less exercise

- Diagram of FEEDBACK:



- *Outline the role of the nervous system in detecting and responding to environmental changes:*
  - The nervous system works to regulate and maintain an animal's internal environment and respond to the external environment
  - The nervous system is made up of two parts, the central nervous system, and the peripheral nervous system:
    - Central Nervous System: This part acts as the CONTROL CENTRE for all of the body's responses. It coordinates all the responses. It is made up of the

brain and the spinal cord. It receives information, interprets it and initiates a response.

- Peripheral Nervous System: This is a branching system of nerves that connects receptors and effectors. This system transmits messages from the central nervous system and back. It acts as a communication channel.

- *Identify the broad range over which life is found compared with the narrow limits for individual species:*
  - *Ambient temperature* is the temperature of the environment
  - The range of temperatures over which life is found is broad compared to the narrow limits for individual species
  - Organisms on Earth life in environments with ambient temperatures ranging from less than 0ºC (such as arctic animals) to more than 100ºC (such bacteria found in boiling undersea volcano vents).
  - However, individual organisms cannot survive this entire range of temperatures
  - E.G. mammals can only survive temperatures from about 0 - 45ºC
  - This means that life is found in a very wide range of temperatures, but individual species can only be found in a narrow temperature range
- *Compare responses of named Australian ectothermic and endothermic organisms to changes in the ambient temperature and explain how these responses assist in temperature regulation:*
  - ECTOTHERMS are organisms that have a limited ability to control their body temperature. Their cellular activities generate little heat. Their body temperatures **rise and fall** with ambient temperature changes. Most organisms are ectotherms. Examples are plants, all invertebrates, fish, amphibians and reptiles
  - ENDOTHERMS are organisms whose metabolism generates enough heat to maintain an internal temperature independent of the ambient temperature. Birds and mammals are endotherms.
  - **ECTOTHERM** RESPONSES TO CHANGING TEMPERATURE:
    - Controlling Exposure: The **goanna** controls its body exposure to the sun by sun baking in the cool morning, and staying in shade during the hot hours.

- Hibernation: The **bogong moths** "hibernate" in hot weather (this is called aestivation). During summer, they gather in caves, their metabolism slows and the body temperature drops. This is to maintain body temperature.
- Shelter: The **central netted dragon** stays in sheltered areas to avoid extreme heat. They can dig burrows or seek shelter in caves or crevices. This reduces the effect of heat on their body.
- Nocturnal Activity: **Brown snakes** can change into nocturnal animals when the temperature becomes very hot. Many desert animals sleep in burrows during the day and are active at night, to escape the heat.

– **ENDOTHERM** RESPONSES TO CHANGING TEMPERATURE:

- Migration: The **short-tailed shearwater** migrates to equatorial regions during the winter months. This is to avoid the cold weather, as the bird only breeds in warm weather.
- Insulation: The **superb parrot** contracts the muscles controlling its feather in cold conditions, fluffing up its coat. This maintains a later of trapped air as insulation. This air reduces heat exchange with the environment.
- Evaporation: The **red kangaroo** licks its arms to cool itself. The evaporation of the saliva cools its skin.
- Nocturnal Behaviour: **Hopping mice**, and many other Australian endotherms, are nocturnal. This is to prevent overheating, and to reduce moisture loss.

- *Identify some responses of plants to temperature change:*
  - Plants respond to temperature change by altering their growth rate – E.G. Some Eucalyptus trees grow more in spring than in winter.
  - In extreme heat or cold, plants can die, but leave behind dormant seeds.
  - Plants may die above the ground, but leave bulbs, roots, rhizomes or tubers to survive underground. These then sprout when favourable conditions return
  - Some plants can change the orientation of their leaves in relation to the sun at different times of the sun, thus controlling temperature
  - Leaves hang down vertically to reduce sun exposure

2. Plants and animals transport dissolved nutrients and gases in a fluid medium:

- *Identify the forms in which each of the following is carried in mammalian blood:*
  - *Carbon Dioxide*
  - *Oxygen*
  - *Water*
  - *Salts*
  - *Lipids*
  - *Nitrogenous wastes*
  - *Other products of digestion*

– **Transporting Substances In The Blood**:

- CARBON DIOXIDE:
  - It is produced as a waste product of respiration in body cells. After entering the bloodstream it may:
    1. Be converted into carbonic acid AND THEN changed into hydrogen carbonate ions. This change from carbon dioxide to carbonate ions happens on the red blood cells. The ions are transported dissolved in the plasma **(only 70% of the carbon dioxide)**.

Carbon Dioxide + Water ⟶ Carbonic Acid ⟶ Hydrogen Ions + Hydrogen Carbonate Ions

$$CO_2 + H_2O \longrightarrow H_2CO_3 \longrightarrow H^+ + HCO_3^{-1}$$

    2. Bind to haemoglobin in erythrocytes forming *carbaminohaemoglobin* **(only 23% of the carbon dioxide)**.
    3. Be dissolved directly in the plasma **(only 7% of the carbon dioxide)**.
- OXYGEN:
  - Oxygen is needed in the body for respiration. It is brought in across the respiratory surfaces of the lungs.
  - It binds with haemoglobin in red blood cells, forming *oxyhaemoglobin.*

- WATER:
  - Water is the solvent of plasma – it makes up the bulk of blood volume
  - It makes up 60% of the volume of blood
- SALTS:
  - These are transported directly dissolved in the plasma
  - E.G. sodium, potassium, magnesium, etc
- LIPIDS:
  - Digested lipids are changed into *triglycerides* (this happens in the lining of the small intestine).
  - Lipids are transported as **chylomicrons** – these are clusters of triglycerides, phospholipids and cholesterol, wrapped in a coat of protein.
  - These are released into the lymph and eventually pass into the veins
- NITROGENOUS WASTES:
  - Wastes such as ammonia are changed in <u>urea</u>
  - Urea is transported dissolved in the plasma
- OTHER PRODUCTS OF DIGESTION:
  - Includes amino acids, sugars, glycerol and vitamins
  - They are mainly water soluble and transported in the plasma

- *Explain the adaptive advantage of haemoglobin:*
  - <u>Adaptive Advantage:</u>
    - If blood carried oxygen *without* haemoglobin, the oxygen would have to be dissolved directly into the plasma (into water).
    - Oxygen is not very soluble in water
    - If oxygen was carried only by being dissolved in blood plasma, 100 ml of water would only be able to carry 0.2 ml of oxygen
    - The presence of haemoglobin increases the oxygen carrying capacity of blood by **100 times**. 100 ml of blood actually carries 20 ml of oxygen.
    - Dissolved only ----> 0.2 ml O_2 / 100 ml blood
    - Haemoglobin ----> 20 ml O_2 / 100 ml blood

- This ability of blood to carry large quantities of oxygen gives mammals a considerable survival advantage
- Mammalian cells need a lot of energy and therefore must have a continual supply of OXYGEN for RESPIRATION
- The extra energy allows mammals to be active, as well as grow large.

- *Compare the structure of arteries, capillaries and veins in relation to their function:*
  - ARTERIES:
    - Carry blood away from heart (high blood pressure)
    - The pressure created by the heart's pumping creates great stress in the arteries
    - This is why the arteries are *thick walled, elastic and muscular*.
    - The arteries are not motionless; they have muscle fibres in them which can contract and relax.
    - This contracting maintains the pressure on the blood, so that the blood travels in spurts towards the body tissues (the contracting and relaxing also creates the pulse on your wrist or neck).
    - The muscle fibres of the arteries also maintain the rate of the flow of blood.
    - Arteries usually carry oxygenated blood
  - CAPILLARIES:
    - Capillaries are an extension of the inner layers of the arteries and veins
    - Capillaries connect arteries and veins
    - Capillaries are only one cell thick, and are so narrow, that only one red blood cell can pass at a time.
    - Capillaries surround all tissue cells
    - Thus, they provide a very large surface area over which exchange of materials between blood and body cells can occur.
  - VEINS:
    - Veins carry blood back to the heart
    - Veins are not under a lot of stress - blood pressure is low
    - This is why they have *thinner walls than arteries, less muscle and a wider diameter* (large lumen).

- Since there are no thick muscular walls to keep the blood pulsing along, the veins have a series of valves which prevent the blood from back-flowing on its way back up to the heart.
- The veins also run through muscles, such as your leg muscles, and as you use these muscles, they press on the veins, pushing blood through the veins.

- *Describe the main changes in the composition of the blood as it moves around the body and identify tissues in which these changes occur:*
  - PULMONARY CIRCUIT (Lungs):
    - Blood enters the right atrium of the heart via the vena cava (major vein):
      - The blood is deoxygenated, and high in carbon dioxide
      - It is low in glucose and other nutrients; it is also high in urea, other nitrogenous wastes and various poisons.
    - As the heart beats, the right ventricle pumps the blood through the pulmonary artery, to the **lungs**:
      - Here the blood gains oxygen, and loses its carbon dioxide.
      - The blood then enters the left atrium via the pulmonary vein.
  - SYSTEMIC CIRCUIT (Body):
    - The left ventricle pumps oxygenated blood to the body through the aorta.
    - In the body, various changes occur to the blood.
      - The blood loses oxygen and gains carbon dioxide in **all** body cells, as respiration occurs. Glucose levels also drop.
    - In the **LIVER**:
      - Levels of glucose are regulated – excess glucose is changed to glycogen, or glycogen stores are changed to glucose (if needed)
      - Excess amino acids are changed to ammonia, and then to urea
      - Poisons are also reduced, as the liver changes them to less toxic forms
    - In the **INTESTINES**:
      - Levels of nutrients from digestion increase.
      - Glucose, amino acids, ions, lipids and other substances from food enter the blood. The increase is through the small intestines reabsorption of food

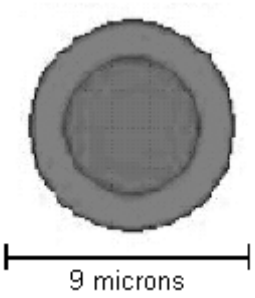
- In the **KIDNEYS**:
  - Salt and water levels are regulated
  - All urea is removed, toxins are excreted into the urine
- The changed blood, again highly deoxygenated, then flows back to the pulmonary circuit.

- *Outline the need for oxygen in living cells and explain why the removal of carbon dioxide from cells is essential:*
  - All living cells need oxygen for respiration.
  - As a result of respiration, carbon dioxide is produced
  - When carbon dioxide dissolves in water, it makes carbonic acid.
  - This means that if a lot of carbon dioxide is produced, the body cells (and the blood and lymph) will become **acidic**.
  - As studied before, enzymes can only function within a specific pH range
  - So an increase in carbon dioxide will result in a lowering of pH, which will affect the overall metabolism of the body.
- *Describe current theories about processes responsible for the movement of materials through plants in xylem and phloem tissue:*
  - XYLEM:
    - Transport of water is passive and depends on *transpiration* and the physical properties of water:
      - Transpiration: Evaporation of water from the leaf cells through the stomates initiates the pull of the TRANSPIRATON STREAM. Water is then drawn up the xylem tubes to replace this loss. The low concentration of water at the roots allows diffusion of water in.
      - Cohesion: Water molecules tend to bind together, forming a continuous column in the xylem, which replaces any loss
      - Adhesion: Water molecules stick to the sides of the xylem tubes (cellulose walls), pulling the water up the tubes.
    - The movement of water through narrow tubes is called CAPILLARITY
    - It is caused by the two forces of COHESION and ADHESION

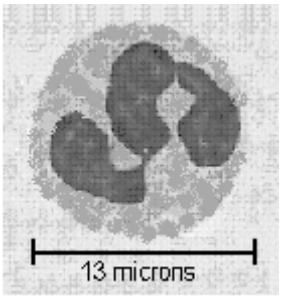
– PHLOEM:
  - Movement of organic molecules, eg sugars, amino acids and hormones, in the phloem is called *translocation.*
  - Materials are transported both up and down the stem. Materials are distributed especially to the *growing points* and *reproductive structures*, including developing fruits and seeds
  - Flow of materials in the phloem is an active process that requires energy
  - It is thought to occur by a mechanism called the source-path-sink system and is driven by a gradient generated osmotically
  - The *source-path-sink* THEORY:
    - In the plants, there are SOURCES of nutrients, e.g. leaf cells are the sources of glucose. As the glucose builds up, the cells transport the glucose by active transport into the phloem tubes, by 2 ways:
      - SYMPLASTIC LOADING: Sugars and nutrients move in the cytoplasm from the mesophyll cells to the sieve elements through plasmodesmata joining adjacent cells (NOTE: Plasmodesmata have not been found in all plants)
      - APOPLASTIC LOADING: Sugar and nutrients move along the cell walls to the sieve tube. Then they cross the cell membrane by active transport.
    - As sugars enter the phloem the concentration of phloem sap increases and the. This causes the entry of water by osmosis from the surrounding cells. This resulting pressure causes water and dissolved solutes to flow towards a SINK.
    - A sink is a region of the plant where sugars and other nutrients are actively begin removed from the phloem. As sugars move out of the phloem, water flows out with them. This reduces the pressure in the sieve cells at the sink region.

- *Use the light microscope to estimate the size of red and white blood cells and draw scaled diagrams of each:*

– RED BLOOD CELLS (Erythrocytes):
  - **Size:** 6-9 µm
  - **Shape:** Bi-concave discs
  - **Function:** Transport of oxygen.
  - They have no nuclei; they only live for 3 months. After this they are destroyed in the liver or spleen.
  - 5-6 million in every millilitre of blood.
  - They are produced in the bone marrow



– WHITE BLOOD CELLS (Leucocytes):
  - **Size:** 12-15 µm
  - **Shape:** Irregular shape; can change shape
  - **Function:** To defend against disease
  - Only 4-12 thousand per millilitre of blood
  - They are the largest blood cell
  - They have nuclei, unlike red blood cells
  - They are produced in the lymph glands.



- *Analyse information from secondary sources to identify current technologies that allow measurement of oxygen saturation and carbon dioxide concentrations in blood and describe the conditions under which these technologies are used:*

Technology	How it Works	The Conditions It Is Used
Pulse oximeter	• Measures O_2 levels • Device like a peg sits on the finger and measures the transmission of light through tissues • Measures the amount of oxygen in arterial blood • There is a large difference between red light absorbed by	• Used in many conditions – this is because it is painless, easy to apply and quick to give results. • Can be used as a general check-up procedure to analyse O_2 levels • Also used during surgeries, to monitor patients under anaesthesia • Also used to monitor premature babies that are in neo-natal wards.

	haemoglobin compared to oxyhaemoglobin	
Arterial blood gas (ABG) analysis	• Measures O_2 and CO_2 levels. • Uses electrochemical methods • Measures partial pressure (or the concentration) of O_2 and CO_2 in the blood • Measures saturation of oxygen (which is the amount of oxygen combined to haemoglobin compared to the maximum) • Measures levels of bicarbonate and pH (to show CO_2 levels) • This analysis evaluates how effectively the lungs are delivering oxygen and removing carbon dioxide	• Used when there are signs of dangerously low oxygen or high carbon dioxide levels • Helps for diagnosing as well as monitoring patients • Helpful for monitoring patients under anaesthesia, in intensive care, in accident or emergency facilities and for premature babies • Eg, a patient in a coma can have their blood gases regularly monitored

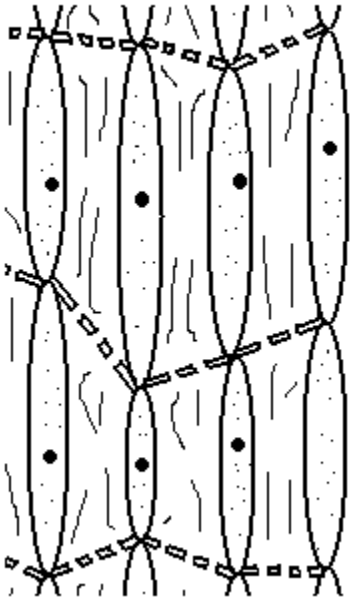
- *Analyse information from secondary sources to identify the products extracted from donated blood and the uses of these products:*
  - RED BLOOD CELLS: Used to increase the amount of oxygen that can be carried to the body's tissues; given to anaemic patients, or people whose bone marrow do not make enough red blood cells
  - PLATELETS: Used to make the blood clot; is given to people with cancer of the blood (leukaemia or lymphoma). Patients undergoing chemotherapy, whose blood does not make enough platelets, are given this.
  - PLASMA: This liquid portion of the blood, is given to people with clotting disorders (such as haemophilia), and also used to adjust the osmotic pressure of the blood (to pull fluids out of tissues).
  - WHITE BLOOD CELLS: Infection fighting component of the blood. Very rarely given, but are used when cell count is very low

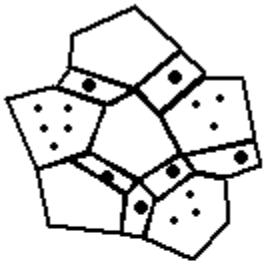
- IMMUNOGLOBULINS: Also called gamma globulins, immune serum, or antibodies, these are also infection fighting parts of the blood plasma. Given to people who have difficulty fighting infections, eg AIDS sufferers.

- *Analyse and present information from secondary sources to report progress in the production of artificial blood and use available evidence to propose reasons why such research is needed:*
  - The problems of using real blood:
    - Shortage of real blood
    - It has to be 'cross-matched'. This is because, if you receive the wrong type of blood, it can be fatal. This is a great disadvantage in emergency situations.
    - It has to be free of infectious agents. Only blood that is free of bacteria and infectious agents (such as HIV) can be used. Testing the blood is costly.
    - It has a short shelf-life. Because red blood cells only survive for 3 months, the blood has a short life span (blood can only survive for 3-4 weeks).
  - Some proposed replacements for blood:
    - <u>Perflurochemicals</u> (perflurocarbons):
      - Synthetic and inert, are completely sterile
      - Cheap to produce, compared to using real blood.
      - Can dissolve 5 times more oxygen than blood.
      - Free of biological materials, therefore no risk of infections
      - BUT - must be combined with other materials to mix in with the bloodstream (eg lecithin).
    - <u>Haemoglobin Based Oxygen Carriers (HBOCs):</u>
      - Made from haemoglobin extracted from red blood cells
      - Haemoglobin is not contained in membrane - cross matching unnecessary
      - Can be stored for a long time
      - BUT - haemoglobin tends to oxidise to a different form, break down, and can no longer carry oxygen.
    - <u>Dextrose Solution:</u>
      - Made of 4% glucose solution in a fluid with equal salinity to blood
      - Only used to restore blood pressure after accidents.

- *Draw transverse and longitudinal sections of phloem and xylem tissue:*
  - PHLOEM:

Longitudinal **Transverse**





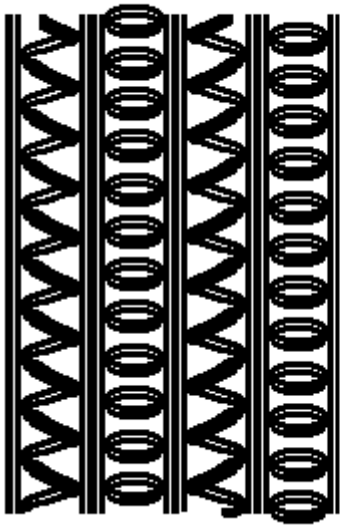
Sieve cells surrounded by companion cells

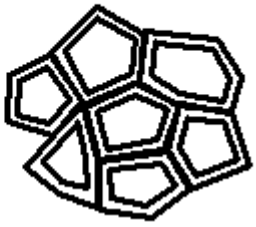
Cells are alive - nuclei present in companion cells

Sieve plates connect sieve tubes

  - XYLEM:

Longitudinal **Transverse**





Thick walls

Lignified with rings or spirals

Cells are dead - no nucleus

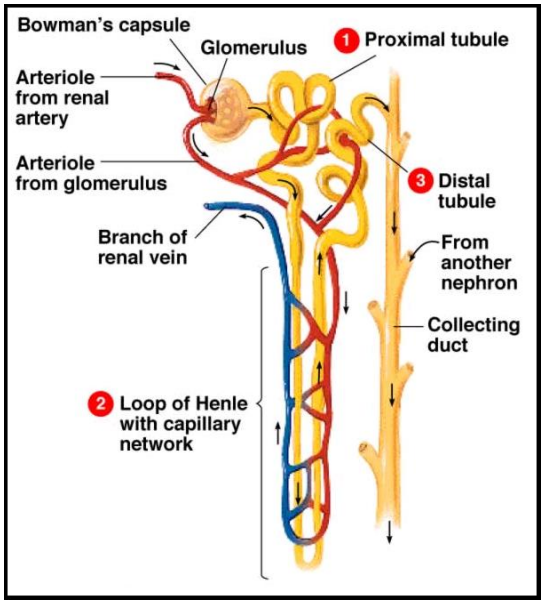
3. Plants and animals regulate the concentration of gases, water and waste products of metabolism in cells and in interstitial fluid:

- *Explain why the concentration of water in cells should be maintained within a narrow range for optimal function:*
  - Water makes up around 70-90% of living things; it is essential for life
  - Water is the solvent of all metabolic reactions in living cells, and sometimes directly takes part in it (eg. Respiration)
  - RECALL:
    - *Isotonic*: Concentration of solutes outside the cell is the same as inside the cell. No overall movement of water.
    - *Hypertonic*: Concentration of solutes is greater outside the cell than inside. Water tends to move out of the cell.
    - *Hypotonic*: Concentration of solutes is greater inside the cell than out. Water tends to move inside the cell.
  - Living cells work best in an isotonic environment
  - The levels of water in cells needs to be kept relatively constant
  - Any change in the concentration of solutes will result in a change in the levels of water in cells which usually results in death (either dehydration or cell bursting)
  - Enzymes also require specific conditions of functioning, some of which could relate to the levels of water and solutes in cells.
  - This is why the concentration of water must be kept constant: To ensure the proper functioning of living cells.
- *Explain why the removal of wastes is essential for continued metabolic activity:*
  - As a result of metabolism, many waste products are formed (e.g. CO_2)
  - If these were allowed to accumulate, they would slow down metabolism and kill the cells (e.g. excess CO_2 increases pH, affecting enzyme function)
  - This is why they need to quickly be removed, or converted into a less toxic form.

- When proteins and amino acids are broken down (in a process called deamination), a nitrogenous waste called ammonia, is produced
- Ammonia is highly toxic and must be removed or changed to a less toxic form

- *Identify the role of the kidney in the excretory system of fish and mammals:*
  - The primary role is osmoregulation.
  - This is the regulation of salt and water levels in the body
  - Fish do not excrete nitrogenous wastes through the kidneys; they use their gills
  - Their urine contains mainly excess water and salts
  - Mammals' urine contains urea as well as water and salts
  - The kidneys ensure that the concentration of blood and interstitial fluid is constant
- *Explain why the processes of diffusion and osmosis are inadequate in removing dissolved nitrogenous wastes in some organisms:*
  - Diffusion and osmosis are both examples of passive transport, relying on random movements of molecules.
  - Diffusion is too slow for the normal functioning of the body and is not able to selectively reabsorb useful solutes.
  - Osmosis only deals with the movement of water and thus would only allow water to move out of the body, not the nitrogenous wastes.
  - In the kidney, some useful products are reabsorbed into the body – this would not be possible with diffusion (active transport needed)
  - Osmosis without active reabsorption of water would result in excess water loss
  - The kidney functions by using excreting all the blood substances in the nephron 'outside' the body and then selectively (actively) reabsorbing useful materials
- *Distinguish between active and passive transport and relate these to processes occurring in the mammalian kidney:*
  - Active transport uses energy to transport substances across a membrane it would normally not be able to cross due to a diffusion gradient or its own properties
  - Passive transport is the movement of substances across a membrane without energy expenditure (this is **diffusion** and **osmosis**) – completely random.

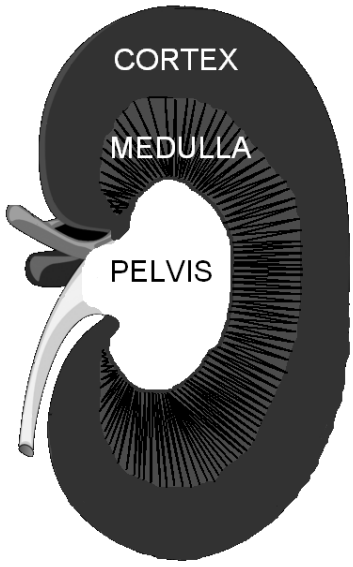
- A kidney is made up of around a million nephrons. It is within the nephrons that the processes of **filtration**, **reabsorption** and **secretion** occur.
- The STRUCTURE of a nephron:
  - It is a long twisted tubule made up of sections: a **Bowman's capsule**, connected to (1) a **proximal tubule**, leading to the (2) **loop of Henle**, which connects to (3) the **distal tubule**. This all joins to the collecting duct which leads to the bladder.



- The nephrons are densely surrounded by *capillaries* (this is to provide a large surface area for excretion).
- Three processes occur in the nephrons (kidneys):
  - Filtration: Within the Bowman's capsule is the glomerulus, a dense clump of capillaries. The blood pressure here is so high that fluid and substance from the blood are forced into the Bowman's capsule, and form a fluid called the *glomerular filtrate*. It flows into the nephron and contains:
    - Substances the body can reuse: Glucose, water, amino acids, etc.
    - Wastes: Urea and poisons.
  - Reabsorption: The substances the body can reuse are reabsorbed into the capillaries surrounding the nephron. Eg, vitamins and hormones. This is active transport and requires energy. Some other substances passively re-enter the blood. Eg, water by **osmosis** and salts by **diffusion**. This occurs in the proximal and distal tubules and in the loop of Henle (discussed in detail later).
  - Secretion: This is the process where the body **actively transports** substances from the blood into the nephron. Some toxins, such as urea, tend to diffuse back into the blood, so it must be secreted back into the nephron. It is also done to regulate salt and water levels again, or to remove additional toxins. This is active transport.

- *Explain how the processes of filtration and reabsorption in the mammalian nephron regulate body fluid composition***:**
  - The nephron is a regulatory unit; it absorbs or secretes substances in order to maintain homeostasis.
  - This regulation maintains the constant composition of body **fluids**.
  - Salts and water are adjusted to maintain fluid concentration
  - Different ions also adjusted to maintain pH.
  - These different processes happen in the different sections of the nephron.
  - Proximal Tubule:
    - Bicarbonate ions are reabsorbed into the capillaries into the blood from the nephron, hydrogen ions are secreted out. This maintains the pH of the blood.
    - Drugs, such as aspirin, penicillin and poisons are secreted out of the blood
    - Regulation of salts also occurs here. Sodium ions are actively reabsorbed and chlorine ions follow passively. Potassium ions are also reabsorbed
  - The Loop of Henle: It has a **descending** limb and an **ascending** limb
    - In the descending limb, it is *permeable to water*, not salt.
    - Water passes out of the nephron and into the capillaries by osmosis
    - In the ascending limb, the walls are *permeable to salt*, but not water
      - Ascending limb is thin-walled at the bottom, and thick-walled at the top.
    - Salt passively passes out into the capillaries at the bottom, thin-walled section, but is actively passed out in the top, thick-walled section.
  - The Distal Tubule:
    - Selective reabsorption of sodium ions and potassium ions occurs here again, to regulate the pH of the blood, and the concentration of salts.
  - The Collecting Duct:
    - This is the end of the nephron, and connects to the ureters.
    - The walls are permeable to water only, and water is transported out accordingly to the needs of the body
    - The final filtrate is called urine.

- *Identify the regions of the mammalian kidney involved in the excretion of waste products:*
  - The kidney is made up of three sections, the pelvis, the medulla and the cortex
  - The cortex contains the glomeruli. It is very dark red due to the capillaries
  - The cortex is involved in the **filtration** of blood
  - The medulla contains the nephron tubules, as can be observed by the striped appearance of the medulla
  - This section is involved in the reabsorption and secretion of substances
  - The pelvis is where all the collecting ducts connect to
  - The collecting ducts reabsorb water
  - The renal artery, renal vein and ureters are all connected to the pelvis.



- *Compare the process of renal dialysis with the function of the kidney:*
  - People with dysfunctional kidneys are not able to remove wastes such as urea
  - They have to undergo renal dialysis to regulate their blood
  - The process:
    - The blood is extracted from the body from a vein and passed into a dialyser, which is a bundle of hollow fibres made of a partially permeable membrane
    - The dialyser is in a solution of dialysing fluid, which has similar concentrations of substances as blood
    - The dialyser only allows wastes to pass through, and not blood cells and proteins. In this way it is similar to the filtrations stage of the nephron
    - The wastes diffuse into the solution, and it is constantly replaced
    - The anti-clotting agent, heparin, is also added to prevent clotting
    - The blood is then returned to the body
  - Comparison of dialysis and normal kidney function:

Kidneys	Renal Dialysis
- Active and passive transport is used throughout the nephron. - Uses a series of membranes (nephrons) which are selectively permeable - Continuous process; very efficient - Useful substances are reabsorbed actively by the kidney	- Only passive transport is used - Also uses membranes (but artificial) which are selectively permeable - Slow process, occurs a few times a week for patients - Useful substances diffuse into blood from dialysing fluid, no reabsorption

- *Outline the role of the hormones, aldosterone and ADH (anti-diuretic hormone) in the regulation of water and salt levels in blood:*
  - ADH (Anti-Diuretic Hormone):
    - Also called vasopressin
    - Controls the reabsorption of water by adjusting the permeability of the collecting ducts and the distal tubules.
    - It is made in the hypothalamus in the brain, but stored in the pituitary gland
    - Receptors in the hypothalamus monitor the concentration of the blood:
      - *High Salt Concentration:* ADH levels increased, collecting ducts and distal tubules become more permeable to water, more water reabsorbed, concentration returns to normal. (Concentrated urine)
      - *Low Salt Concentration:* ADH levels reduced, collecting ducts and distal tubules less permeable, less water absorbed, concentration returns to stable state. (Dilute urine)
    - ADH does not control the levels of salt in the blood. It only controls the *concentration* of salt through water retention.
  - Aldosterone:
    - Produced and released by the adrenal glands, which sit above the kidneys
    - Controls the amount of salt in the blood by regulating the reabsorption of salt in the nephrons
    - *High Salt Levels:*
      - High blood volume and blood pressure due to water diffusing in.

- Levels of aldosterone decreased.
- Less salt reabsorbed, less water diffusing in
- Salt level decreased, blood volume and pressure decreases

▪ *Low Salt Levels:*

- Low blood volume and blood pressure due to water diffusing out.
- Levels of aldosterone increased.
- More salt reabsorbed, more water diffusing in
- Salt levels increase, blood volume and pressure increase

- *Define enantiostasis as the maintenance of metabolic and physiological functions in response to variations in the environment and discuss its importance to estuarine organisms in maintaining appropriate salt concentrations:*
  - DEFINITION: Enantiostasis is the maintenance of metabolic and physiological functions in response to variations in the environment.
  - An estuary is where a river meets the sea, and freshwater mixes with saltwater
  - In such an environment, the salinity levels are always changing dramatically.
  - From low tide to high tide, water can flow in from either the salty ocean, or from freshwater rivers – this causes great variation in the levels of salt in the water.
  - Organisms living in such an environment need to have mechanisms to cope with such changes in order to survive. The mechanisms are all collectively called enantiostasis
  - Animals (like fish) can move to avoid changes (or shellfish opening and closing),
  - Plants must have mechanisms to help them cope with these changing environmental conditions.
- *Describe adaptations of a range of terrestrial Australian plants that assist in minimising water loss:*
  - **Spinifex grass** has extensive root systems that can reach underground water. Their leaves are also long and thin to reduce water loss, and can roll up to hide their stomates, which prevents water loss.

- **Eucalyptus** trees are hard with waxy cuticles – this reduces the amount of water loss through transpiration. Their leaves also hang vertically to reduce sun exposure.
- **Banksia** leaves have sunken stomates – this reduces transpiration
- **Wattle** leaves are small and hairy – the small size means less evaporation of water, and the hairy leaves reduce the transpiration by trapping water.
- **Grevillia** plants have narrow leaves to reduce the surface area, reducing transpiration rates.

- *Outline the general use of hormone replacement therapy in people who cannot secrete aldosterone:*
  - The adrenal gland secretes aldosterone
  - Without aldosterone, the body would not be able to reabsorb salt (specifically sodium ions) and this would cause severe dehydration, and excessive potassium.
  - This would result in brain damage and death
  - Fludrocortisone is an artificial hormone which can be used as a treatment for people who cannot secrete aldosterone (due to a damaged adrenal gland; Addison's disease). It does the job of aldosterone.
- *Analyse information from secondary sources to compare and explain the differences in urine concentration of terrestrial mammals, marine fish and freshwater fish:*
  - **Freshwater Fish:**
    - Osmotic Problem: They are hypotonic to their environment. Water will tend to diffuse INTO their bodies. Salts will diffuse out.
    - Role of Kidney: Removes excess water. Produces large amounts of dilute urine. Kidneys also reabsorb salts. They also rarely drink water.
    - Urine: Large amount but dilute.
  - **Marine Fish:**
    - Osmotic Problem: Hypertonic to environment. Water diffuses out. High salt levels present in the water

- Role of Kidney: Continually drinks water. Kidneys reabsorb water, while actively secreting salts. Small amounts of concentrated urine. Salt is also excreted across gills.
- Urine: Small, concentrated amount.

– **Terrestrial Mammals:**

- Osmotic Problem: Water needs to be conserved.
- Role of Kidney: Regulates concentration of blood, while at the same time excretes urea and conserves water.
- Urine: Concentration changes with the availability of water, as well as temperature and water loss through sweat. Water levels in blood rise, urine amount rises, and concentration decreases and vice versa.

- *Explain the relationship between the conservation of water and the production and excretion of concentrated nitrogenous wastes in a range of Australian insects and terrestrial animals:*

– **Ammonia** is the direct result of amino acid breakdown (deamination) and is a waste product of all organisms. It is very water soluble, but VERY toxic, and must be removed quickly, or changed to a less toxic form.

– The removal of ammonia would require large volumes of water, and this is not possible for animals or insects that seek to conserve water

– **Aquatic Animals and Fish***:* These organisms directly release AMMONIA into the environment. This uses a lot of water, but they have no need to conserve it. Ammonia is very water soluble and is excreted through the gills.

– **Terrestrial Animals***:* Releasing ammonia would be impossible due to lack of water. Instead, land-dwellers change ammonia into less toxic forms and release it periodically. Mammals change it into UREA and release it as urine. (E.G. Kangaroos, wallabies, hopping mice, koalas, etc.) Australian animals release very concentrated urine, and are able to tolerate high levels of urea in their bodies.

– **Birds***:* Birds change ammonia into URIC ACID, a whitish paste which uses hardly any water. This is lighter than using urea, and helps in flight.

– **Insects**: Insects also change ammonia to URIC ACID (E.G. Acacia psyllids)

- *Process and analyse information from secondary sources and use available evidence to discuss processes used by different plants for salt regulation in saline environments:*
  - Halophytes are plants that can tolerate high salt levels
  - They are commonly found in areas such as estuaries.
  - Grey Mangroves:
    - *Salt Exclusion:* Special glands in the mangroves can actively exclude the salt from the water, so that the water absorbed has a lower salt concentration than the water in the environment.
    - *Salt Accumulation:* Salt is accumulated in old leaves that drop off, so that the salt is out of the plant's system
    - *Salt Excretion:* Salt can be excreted from the underside of the leaves of the mangrove plants; salt crystals form under the leaves.
  - Saltbushes:
    - *Salt Accumulation*: This plant stores its excess salt in swollen leaf bases, which drop off, ridding the plant of salt.
- *Describe structures in plants that assist in the in the conservation of water:*
  - **Eucalyptus:**
    - Waxy, hard leaves: Reduces water loss by reducing the rate of transpiration from the leave surface
    - The leaves hang vertically, and this reduces the water loss, conserving water
  - **Banksia:**
    - Leaves have sunken stomates – this reduces transpiration
  - **Wattle:**
    - Leaves are small and hairy – the small size means less evaporation of water, and the hairy leaves reduce the transpiration by trapping water.
  - **Grevillia:**
    - Plants have narrow leaves to reduce the surface area, reducing transpiration