BIOLOGY

Maintaining A Balance

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1. MOST ORGANISMS ARE ACTIVE IN A LIMITED TEMPERATURE RANGE

ENZYMES

Role

Enzymes are large biological molecules responsible for the vital chemical reactions constantly occurring that sustain life. These organic catalysts help speed up reactions in the body by lowering the activation energy required for the reaction to occur. Enzymes also enable reactions to occur at lower temperatures, which means body temperatures don't need to be so high.

Basic functions such as respiration, digestion and photosynthesis wouldn't be able to sustain life without particular enzymes.

Metabolism: the sum of all chemical reactions occurring in an organism. Concerned with managing the material and energy resources of the cell and the building up, maintenance of and breaking down of living tissue.

Process

Enzymes only work in a narrow range of temperature and pH, with changes altering the shape of the enzyme.

They are only required in small amounts and are highly specific to one reaction, remaining unchanged at the end of that reaction.

Each molecule has a particular 3D shape fitting its substrate perfectly. An enzyme acts by combining with the substrate. The reaction takes place at the binding site of the enzyme and substrate – **the active site**.

This is the lock and key model. Many enzymes operate according to the lock and key model, and others operate according to the induced fit model.

Chemical Composition

They are made of long chains of amino acids (proteins) held together by peptide bonds, Contain carbon, hydrogen, oxygen and nitrogen. The folded 3D shape is related to enzyme specificity.

Factors that affect enzyme activity:

- **Presence of heavy metals (mercury, zinc)**
- **Temperature**

Up to a point, the rate of enzyme reactions increases with an increase in temperature, because the warmer temperature makes substrate molecules collide with active sites more frequently. There is an optimum enzyme temperature- most human enzymes at body temperature of about 35-40 degrees c. Enzymes that live in hot springs can have optimum temperatures of 70 degrees c or higher.

Beyond the optimum temperature the rate decreases sharply. Too much heat destroys the specific shape of the active site by disrupting bonds, and it is denatured. Partially denatured enzymes may regain their correct shape on cooling, but complete denaturisation is irreversible.

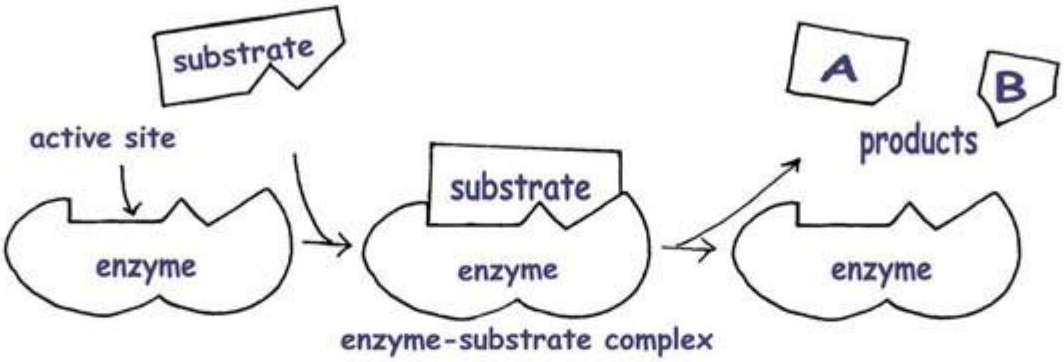
- **pH levels**
  pH can affect enzyme activity by changing the shape of the enzyme. The optimum pH is mostly 6-8 but there are exceptions- e.g. Pepsin, a stomach enzyme works best at pH 2.

- **Enzyme concentration**
  If the amount of enzyme is increased, the reaction rate will increase as more substrates are catalysed in a shorter period of time.

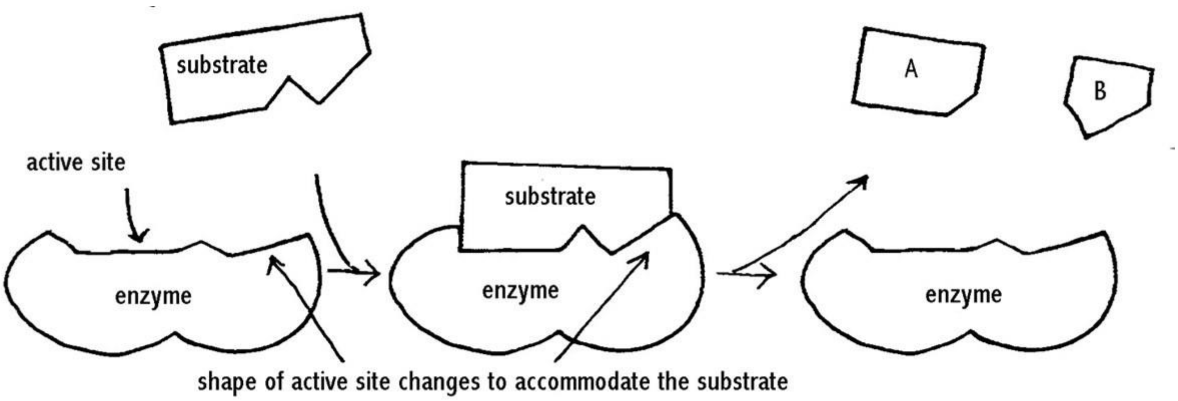
- **Substrate concentration**
  The addition of more substrate will initially increase the rate of reaction if not all active sites of the enzyme are occupied. Eventually there is a substrate saturation point, where all the active sites have been used up by substrate and the addition of more substrate will not affect activity.

- **Presence of coenzymes and cofactors**
  Cofactors are small molecules that help enzymes to act. If they are inorganic (metallic) they are called cofactors, if they are organic molecules (vitamins) hey are known as coenzymes.
  Many enzymes have cofactors and coenzymes without which they cannot catalyse the reaction. The coenzyme usually binds to the active site and the cofactor is either bound to the enzyme or to the coenzyme.

Lock and Key model



Induced Fit model



pH

pH is a way of describing the acidity of a substance by measuring the concentration of hydrogen ions released by acids. The scale ranges from 1-14.

- Pure water has a pH of 7(neutral)
- Acidic is between 0 and 6
- Basic is between 8 and 14

Importance of constant internal environment for optimal metabolic efficiency

Living things are exposed to frequent changes in their external environment. The chemical reactions that support the processes of life need specific internal conditions eg. Keeping temperature, pH and substrate concentration relatively stable for optimal metabolic efficiency and a high level of efficiency for the running of cells is possible.

Homeostasis

Homeostasis: The maintenance of a relatively stable internal environment.

Homeostasis is a dynamic state: an interplay between outside forces that try to control the internal environment and internal control mechanisms that oppose such changes.

This is done through the activity of the nervous and endocrine (hormonal) systems. Their combined activity maintains the composition of cellular fluids and substances at efficient levels for normal cell functioning.

- pH
- Temperature
- Water balance
- Blood sugar levels
- Oxygen levels
- Co2 levels
- Metabolic rate
- Concentrations of dissolved salts and minerals
- Removal of malfunctioning cells or foreign substances
- Blood pressure
- Ions
- Urea
- Red blood cells

Positive Feedback System vs. Negative Feedback System

Positive Feedback System	Negative Feedback System
Any change causes more change in the same direction Eg. A fire growing bigger	Any changes causes the next change to be in the opposite direction Eg. An oven thermostat control
Causes system to grow out of control	
Never results in stability	Results in stability

Homeostasis is negative feedback control

Stimulus - receptor - control centre - effector - response

Homeostasis Stages

1. **Detecting changes from the stable state**
   Receptor: Measures the conditions- skin and the hypothalamus.

2. **Counteracting changes from the stable state**

   Control Centre: Decides how to respond.
   Effectors: Carry out the commands of the control centre and make necessary adjustments- blood vessels, sweat glands, muscles, body hairs, endocrine glands.

<u>THERMOREGULATION</u>

Hypothalamus: At the base of the brain. Constantly monitors the temperature of the blood flowing by

Temperature rises:

- Sweat glands release sweat
- Vasodilation- more blood being sent to the surface of the skin
- Metabolic rate slows (less heat being produced)

Temperature drops:

- Heat can be lost in the body through radiation (infra-red rays 60%) conduction(heat into surrounding air. Heat is lost 24x faster in water because it's moving continually. Moving makes heat be lost faster than still air. 15%) convection(direct contact with objects 3%) and evaporation(22% through skin and lungs when water evaporates from those surfaces)

- Shivering- muscles contract and generate heat

- Vasoconstriction- blood vessels reduce in width to reduce heat loss through radiation

- Goosebumps- trapped air between hair and skin acts as insulation and forms a layer of warm air reducing heat loss

- Metabolic rate speeds up

The role of the nervous system

The nervous system plays an important role in the maintenance of a stable state, consisting of the brain, nerves and spinal cord, working in conjunction with the endocrine system.

Receptors:

Sense organs (skin, eyes, ear, nose and tongue) collect information about the external environment. Receptors within the body collect information about the internal environment (blood pressure, dissolved substances such as c02) Information collected from the environment, collected by a receptor is called a STIMULUS.

Sensory Nerves:

Nerves carry messages from receptors in the form of electrical impulses- sensory nerves.

Spinal Cord:
Passes the electrical messages up to the brain. Some information is processed directly by the spinal cord- producing a very fast response called a reflex.

Brain:
Processes information about external and internal changes. Different parts of the brain use different kinds of information.

Spinal Cord

Effector Nerves

Effectors:
Effectors may act to change internal factors and so maintain homeostasis. Eg. Muscles and glands.

Temperatures of life

Most organisms live in the range of 0-35 degrees Celsius.

Extreme Cold:

- If temperatures are too cold, the enzymes that catalyse the reactions of metabolism are stable but don't work quickly enough.
- Many cell membrane proteins only function properly if they are floating in the lipid bilayer- which then has to be liquid. At low temperatures the lipid bilayer freezes.
- Ice crystals forming in cells can pierce membranes and kill cells.
- Chemical reactions of metabolism run so slowly at low temperatures that life functions are not possible.
- Certain types of algae and photosynthetic bacteria have been found to live within snow and ice.

Cold Water:

- Water environments rarely fall below 4 degrees c, even with ice, and are remarkably stable.
- Mammals and birds need serious insulation to stay warm.

Extreme Heat:

- At around 85 degrees c DNA 'melts'- the double helix splits into two separate strands.
- If temperatures are too warm, enzymes are unstable and rapidly denature.
- Thermophillic bacteria such as Archaea thrive up to 120 degrees C.
- Desert animal species seek shelter in the heat of the day, whilst plants shut down their metabolism and barely survive.

Each individual species of organism, however, has a much narrower range of temperatures over which it can survive. Although individuals may be able to survive within a temperature range, they may only function optimally and be able to reproduce in a smaller temperature band.

Australian ectotherms and endotherms

ECTOTHERMS:

Have no internal mechanisms to maintain a constant body temperature, which is governed by the environmental temperature. Reptiles, amphibians, invertebrates, plants, some fish and many insects.

Ectotherms that live in the **water** have to deal with little temperature variation, and have a body temperature similar to that of its surroundings.

Ectotherms that are **terrestrial** usually have behavioural adaptations to help them cope with the wide range of temperature variations on land. Some insects, fish, frogs and turtles prevent their cells from freezing by having antifreeze substances in their body fluids.

Eg. Blue Tongue Lizard- Lies in the sun to increase its temperature. When blood reaches 28 degrees the snake becomes active. If too hot, it will shelter under rocks, logs, burrows and in leaf litter, preventing a too high body temperature.

Eg. Bogong Moth-Adults migrate to the Australian Alps in summer.

ENDOTHERMS:

Maintain a constant body temperature through metabolic activity. Mammals, birds and some fish.

Rely greatly on having body insulation such as fur, feathers or fat. Having a warm body is energetically very expensive, especially in a cold environment, so they need to consume more food than ectotherms.

Aquatic Endotherms have difficulties maintaining a constant body temperature as water conducts heat rapidly away from the body.

Terrestrial endotherms in **hot** climates such as deserts face the problem of overheating. Most desert animals are small, a structural adaptation giving them a large surface area : volume ratio, and they lose heat quickly. Many also have the ability to vasodilate, a physiological adaptation resulting in more heat being lost to the environment through radiation, convection and conduction.

Terrestrial endotherms in **cold** climates (Australian alps) face the opposite problem. Many have structural adaptations such as a rounded body shape reducing sa/volume ratio and an increase in size.

Eg. Red Kangaroo- Maintains a body temperature of 36 degrees through behavioural, structural and physiological adaptations.

Physiological: pumps warm blood to its forelimbs

Structural: lack of hair on forelimb, large ears with many blood vessels increasing sa/vol ratio for heat loss, thick fur insulation, paleness reflects sun

Behavioural: Licking of forelimb, seeks shade in middle of day

The warm blood is pumped to the forelimb where saliva evaporates from the surface having a cooling effect, like sweating.

Eg. **Fairy Penguins-** Risk losing heat from their extremities- physiological adaptation is a counter-current heat exchange, A special arrangement of arteries and veins. Arteries carrying warm blood to the legs are in close contact with the veins carrying blood in the opposite direction so heat can be transferred from the arterial blood to the vein.

'Blood shunt' in legs- in cold water circulation to feet is shut off to prevent heat loss through the poorly insulated feet.

Responses of plants to temperature change

Temperature changes are one of the main factors controlling germination, the growing season, flowering and seed dispersal. Gene expression in plants can also be influenced by temperature- eg. Primroses are red flowered at room temperature and white flowered above 30 degrees c.

Extreme Cold:

- Lipids in cells crystallise and **cell membranes lose fluidity**
- **Ice** can pierce cell membranes and organelles killing cells
- Some plants have an **ANTIFREEZE chemical** preventing the formation of ice

Cold:

- Usually leads to a period of dormancy
- **Deciduous –** drop leaves to reduce heat loss & leaves can't be protected from freezing. Eg. Beech tree
- **Vernalisation –** Some plants, like tulips, won't flower unless they have been exposed to a certain degree of coldness, ensuring they flower when conditions are warm enough.
- **Plant dies back –** Anything above ground disappears, only the bulb remains protected. Eg. In daffodils.

Heat:

- Usually initiates a **growing response,** maximising use of rainfall and warmer temperatures
- **Smaller leaves-**reduces s/a exposed to heat so less water is lost through stomata. Eg. In geraniums.
- **Stomata open-**release water to cool through evaporation
- **Structure-**thick stems reducing s/a being hit by heat radiation and light colours to aid reflection in desert (cacti) Sclerophyll leaves droop, thick and waxy cuticles avoiding midday sun and increase heat reflectivity.
- **Heat-shock properties-** special proteins protecting enzymes from denaturing from heat.
- **Transpiration** helps cool a plant by evaporation.
- **Radiation-** plant radiates heat to objects in its environment
- **Convection-** air surrounding a plant heats and so rises, carrying heat away from the plant.

Extreme Heat:

- **Stomata close** beyond 30 degrees c to reduce water loss
- If temperature too high **enzymes denature** and metabolism is disrupted, causing possible death
- Fire causes seed dispersal (Banksia, eucalypt) clear fertile ground increases chance of survival.
- Many herbaceous and non-woody plants **die back** leaving only dormant seeds with thick woody coats.

PRAC 1 - Effects on enzyme activity

Temperature Change

Method

1. Make a solution by dissolving a junket tablet in distilled water.
2. Prepare 6 test tubes with 10mL of milk in each.
3. Label tubes as 10j, 40j, 60j, 10c, 40c and 60c.
4. Create three water baths, using hot water, tap water and ice cubes, at temperatures of 10, 40 and 60 degrees. Make sure each water bath remains correct temperature with a thermometer.
5. Place test tubes in their allocated water baths.
6. Into the 'j' tubes, pour 2mL of junket solution. The test tubes without junket will act as a control to see if the milk by itself changes.
7. Tilt test tube every minute to test if milk has set.
8. Record time each tube set.

Results

Test Tube	Time Taken
10j	10mins +
10c	
40j	3mins
40c	
60j	4mins
60c	-

Dependant: time taken for milk to set
Independent: temperature

Improve?

- Repeat
- Using a smaller temperature range
- Maintaining correct temperature accurately

Safety

- Safety goggles
- Hot water
- Glassware

Conclusion:

Temperatures too cold will not allow the enzyme to work, and too hot will cause them to denature. The optimum temperature for junket is around 40 degrees, the temperature of a mammal's body.

Change in pH

Method

1. Make a solution by dissolving a junket tablet in distilled water.
2. Prepare 6 test tubes with 10mL of milk in each
3. Add pH solution to each with known concentrations of pH solutions from for example pH 3, pH 4, pH 5, pH 6, pH 7 and pH 8.
1. Add the same amount of rennin solution with the varying pH to six test tubes of milk.
2. Place in a water bath kept at a constant temperature of 37^{o}C.
3. Time the interval between adding the rennin and curdling of the milk in each test tube.
4. Note that the variables kept constant in each test tube are the junket solution, the type of milk, the temperature of 37^{o}C, and the quantity of milk in each test tube.
5. Comment on which pH is the most effective in curdling the milk.

Results
pH of four curdled soonest

Dependant: Time taken for milk to curdle
Independent: pH

Improve?

- Repeat

Safety?

- Hot water
- goggles

Conclusion:

An optimal pH allows an enzyme to work as efficiently as possible.

Change in substrate concentration

Method

1. Cut up 4 identical cubes of potato
2. Set up 4 test tubes
3. Place all test tubes in a water bath of 37 degrees
4. Add 5mL of hydrogen peroxide to each test tube (1.5%, 3%, 4.5% and 6%)
5. Add a drop of detergent to each test tube
6. Add potato to each tube
7. Measure and record height of foam produced as oxygen bubbles through the detergent.

Results
The level of foam was the highest with 6% hydrogen peroxide

Dependant: amount of foam produced (reaction)
Independent: concentration of hydrogen peroxide

Improve?

- Repeat
- More concentrations

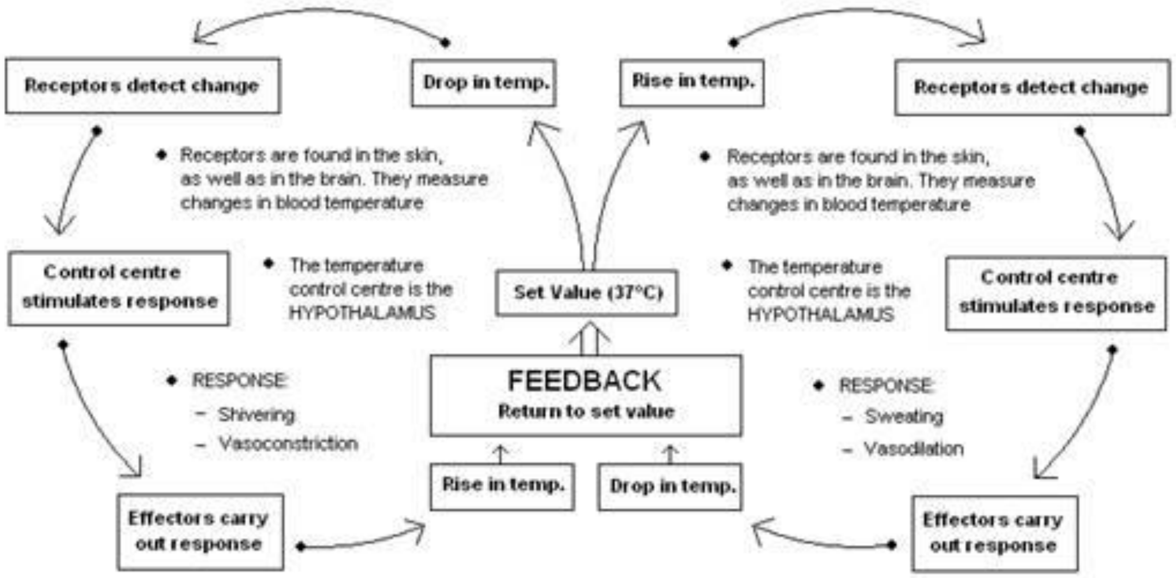
Safety?

- Goggles

Conclusion:

An increase in substrate concentration produces an increase of enzyme activity. (this occurs up until a certain concentration)

Develop a model of a feedback mechanism



Thermometer at room temperature (20degrees) → thermometer near Bunsen burner (raises temperature to 60 degrees) → damp cloth and fan cool temperature → response removed when temperature returns to room temperature → thermometer back at room temperature

Adaptations and responses in Australian organisms to assist temperature regulation

ECTOTHERM: Thorny Devil

Small Australian lizard which lives in the deserts of central and western Australia. Has a short, flattened body covered by thick scaly skin with spines off its back.

The flattened body allows it to lie firmly against the warm sand to absorb heat. Body shape allows quick transfer of heat to inner parts and conserving of water. Thick scaly skin helps insulate from hot and cold conditions.

Lying in the sun and against sand are behavioural adaptations, as it is burrowing into the sand where temperature is lower and humidity higher in times of extreme heat.

The combination of structural and behavioural adaptations assists the lizard to use the environment to regulate its body temperature.

ENDOTHERM: Mountain Pigmy Possum

Small Australian alpine mammal which lives in the mountains of South-Eastern Australia.

Structural adaptations to retain body heat:

- Thick Fur
- Round Stocky Body (Low Surface Area To Volume Ratio) Reduces Radiant Heat Loss
- Short Legs- Reduces Radiant Heat Loss
- Small Ears- Reduces Radiant Heat Loss
- Long Furry Tail

In winter it hibernates (physiological) causing its metabolic rate to fall. A behavioural adaptation during winter is that it rolls itself into a ball to assist in the retaining of heat and the maintenance of body temperature.

2. PLANTS AND ANIMALS TRANSPORT DISSOLVED NUTRIENTS AND GASES IN A FLUID MEDIUM

Blood is the transport medium of mammals. It maintains the internal environment of all organs as it supplies material to every cell in the body and removes the unwanted substances that cannot be allowed to accumulate in cells. Blood consists of 55% plasma, a straw-coloured liquid of which 90% is water. The other components of the blood are red and white blood cells and platelets.

Red blood cells are unique in that they do not contain a nucleus and have a biconcave shape. They are much smaller than white blood cells and more numerous. They contain the protein haemoglobin, a complex protein molecule consisting of four polypeptides, each containing an iron atom. The iron atom has an affinity for oxygen molecules. When haemoglobin is combined with an oxygen molecule, it is called oxyhaemoglobin*.*

Plants carry dissolved mineral nutrients in the xylem vessels and carry food (mostly glucose) in phloem tubes.

The forms in which substances are carried in mammalian blood

Oxygen: Required for cellular respiration

- Carried In haemoglobin in red blood cells

Carbon dioxide: It is produced as a waste product of respiration in body cells. After entering the bloodstream it may:

- Combines with water to form hydrogen carbonate, carried in blood plasma **(70% of co2)**
- Bind to haemoglobin molecule **(23% of co2)**
- Be dissolved in plasma **(7% of co2)**

Salts: Required for many processes and reactions in the body- eg. Muscular movement

- Carried dissolved as ions in plasma

Water: Solvent in which many substances are dissolved

- Makes up 90% of plasma

Lipids: Fats required for cellular energy

- Miscible in water packaged in a protein coat, dispersed in plasma.

Nitrogenous waste: Urea- waste product from cellular metabolism

- Dissolved in blood plasma

Other products of digestion: Sugars & amino acids

- Water soluble and carried dissolved in the blood plasma.

Haemoglobin

Oxygen is not very soluble in water and so cannot be carried efficiently dissolved in the blood plasma.

Most of the oxygen is carried by haemoglobin **(iron containing protein, a red pigment)** in the red blood cells, increasing the oxygen carrying capacity of the blood.

Haemoglobin molecules have a great attraction for oxygen molecules and quickly 'grab' any 02 molecules available. Blood carries thousands of times more oxygen than would be possible by simply dissolving oxygen in the blood plasma.

When oxygenated blood reaches body tissues the high concentration of co2 lowers the pH of the blood slightly, causing the haemoglobin proteins to change shape slightly and release the oxygen molecule, which diffuses into the cells, and the freed haemoglobin molecules can pick up some of the c02 molecules and carry them back to the lungs.

Organisms with blood containing haemoglobin are able to deliver oxygen to cells more efficiently than other organisms with blood that has no haemoglobin, giving the animal a huge survival advantage by moving faster, growing faster and larger and successfully breeding. They can maintain a constant body temperature as they can generate internal body heat by cellular respiration. This allows them to be active in a large temperature range.

The structures and function of arteries, capillaries and veins

Arteries: Heart →body. Thick muscular walls to withstand pressure of pumps. Elastic in order to contract. Carry oxygenated blood (except for the pulmonary artery)

Veins: Body → heart. Low pressure so thin walls. Some contain valves to prevent backflow of blood. Carry deoxygenated blood (except for the pulmonary vein)

Capillaries: Tiny blood vessels that form a network throughout the body so all cells are close to a blood supply. Walls are one cell thick for diffusion- red blood cells travel through in single file. Carry blood between arteries and veins.

Changes in chemical composition of blood in the body as it moves around

Heart → lungs (O_2 taken in by lung capillaries and CO_2 released) → **heart → arteries** (high concentration of O_2, low CO_2 levels) → **organs and tissues** (capillary network- o2 taken in, co2 released0 → **veins** (high concentration of CO_2, low O_2) → **heart**
Co2 decreased and o2 increased.

Lungs
Blood receives *oxygen* and *carbon dioxide* is released

Body Tissue
Blood receives *carbon dioxide* and *oxygen* is released

Stomach Tissue
Water diffuses into the blood. *Some substances, such as alcohol*, pass into stomach tissue from the blood through the walls of the stomach.

Small Intestinal Tissue
Villi- Digested food- *Amino Acids & glucose:* Diffuse into the blood and go straight to the liver (*fatty acids* diffuse into lymph)

Liver
As blood travels through capillaries in the liver, protein fragments can move out of the blood to be broken down into urea, which then diffuses into the blood. Sugars may be removed for temporary storage, or returned to the blood if more energy is needed elsewhere in the body.
Some poisonous *or unwanted substances such as alcohol* are removed.
Some *vitamins, iron and excess lipids* are removed.

Large Intestinal Tissue
Water, salts and vitamins are absorbed in the large intestine and pass into the blood

Kidneys
As blood travels through capillaries around nephrons in the kidney, urea, *Urea, excess water and salts* are removed from the blood to be excreted.

Gland- Endocrine Tissue
Hormones: Secrete hormones directly into blood stream

SUBSTANCE	HOW ITS CONCENTRATION CHANGES
Oxygen	Oxygen enters the blood capillaries from the alveoli in the lung. The pulmonary vein has the highest concentration of oxygen. As the blood flows around the body, the oxygen is released into the tissues to be used in respiration by the body cells. The lowest concentration of oxygen is the pulmonary artery which goes to the lungs.
Carbon Dioxide	Carbon dioxide is a by-product of respiration and enter the blood from body cells which have been respiring. The highest concentration of carbon dioxide is in the pulmonary artery which goes to the lungs. The carbon dioxide is excreted from the lungs.
Nitrogenous Wastes	Urea is formed from protein metabolism in the liver and is removed from the body by the kidneys. The highest concentration of urea is in the renal artery which is delivering blood to the kidney. The lowest concentration is in the renal vein.
Products of digestion	Amino acids, glucose, fatty acids, glycerol enter the blood through the villi in the small intestine. They leave the blood plasma at any site where cells require nutrients. Excess glucose is stored in the liver as glycogen and is released when the body requires more energy.

Oxygen and carbon dioxide in cells

Oxygen is needed in large amounts by cells as it is one of the reactants in respiration. Carbon dioxide, a metabolic waste product, needs to be removed from cells as it reacts with water to form carbonic acid, lowering the pH of the cellular fluid affecting enzyme activity.

The body has responses to maintain co2 levels at desirable levels in the blood. Too much co2 causes an increase in the rate and depth of breathing. Not enough co2 in the blood causes a lower rate and depth of breathing which increases co2 concentration levels.

The movement of materials through plants in xylem and phloem tissue

From soil:

- *WATER* enters the plant by osmosis. Cytoplasm inside plant cells contain many dissolved substances, meaning the water concentration in cytoplasm is lower in soil water, causing water molecules to move from the higher concentration in the soil to the lower concentration inside cells.

- *MINERAL IONS* can also diffuse into root cells, but often using active transport.

Xylem

- Transports water and inorganic ions up the plant from the roots to the leaves using passive transport.

- Xylem tubes are dead, hollow cells joined end to end forming a continuous tube from root to leaf.

COHESIVE FORCES- forces of attraction between water molecules. Maintain and support water column.

ADHESIVE FORCES- forces between water molecules and wall of xylem vessel. Make water column stick to the side of the xylem, supporting it.

TRANSPIRATION STREAM FORCES- evaporation of water from stomata in the leaves has a pulling effect on the water column upwards as water and mineral salts enter the root hair through osmosis, enabling it to reach the leaves.

Phloem

- Transports sugars and other organic materials up and down the plant. This movement is called **TRANSLOCATION-** hydrostatic pressure within phloem vessels that cause water and dissolved minerals to move.

- It is made from living cells joined end to end. The end of each cell is perforated forming a continuous tube.

  APOPLASTIC MOVEMENT THEORY- food and nutrients move along cell walls until they reach the sieve plate in the phloem vessel.

  SYMPLASTIC MOVEMENT THEORY- food and nutrients move from cell to cell through specialised structures called plasmodesmata.

Once food and nutrients are in the phloem vessel they are actively distributed around the plant and removed actively.

- A pump actively moves sugars into the sieve at the source, and at the sink the sugar moves out by diffusion.
- Some species require active transport to unload the sugar.
- If a lot of photosynthesis is occurring, the phloem will carry sugar to storage sites in the roots of the stem.
- The flow of nutrients is caused by pressure differences between the sources and sink tissues. The difference is osmotic pressure, generated by active transport of sugars causing water to flow into or out of cells.

PRESSURE FLOW/MASS FLOW THEORY:

1. Sugars are moved into the phloem by active transport.
2. The increased sugar concentration makes water in these cells less concentrated than in surrounding cells.
3. Water moves from surrounding cells into the phloem cells by osmosis.
4. More water increases the pressure in the phloem cells.
5. Increased pressure causes the substances in the phloem cells to flow to another cell in the plant phloem tissue, and so on, so that substances gradually move through phloem tissue.
6. Dissolved substances, especially sugars, are removed from the phloem tissue and at another location in the plant so that the flow mechanism can continue.

	Structure	**Type of transport**	**Material transported**	**Method of transport**	**Function**
Xylem	Dead, hollow cells joined end to end forming a continuous tube from root to leaf. Has spiral thickenings	Passive	Water, dissolved minerals, ions	Osmosis Capillary effect Cohesion Adhesion Transpiration stream	Caries water and dissolved minerals from roots to leaves.
Phloem	Living cells joined end-to-end. Ends of cells are perforated so each cell opens into the next forming a continuous tube.	Active	Nutrients (glucose from photosynthesis)	Pressure differences causes flow of cytoplasm. Translocation Source → sink	Carries nutrients up and down the plant.

PRAC 2 – Effect of dissolved co2 on the pH of water

Method

1. Add 10 drops of universal indicator to 50mL of water in a beaker.
2. Blow through a straw into the water
3. Observe changes in colour

Results
Colour changes from green to red/orange/yellow

Dependant: CO_2 levels
Independent: pH

Improve?
- Repeat

Safety?
- Safety goggles

Conclusion: Dissolved co2 in water decreases pH- becomes more acidic

PRAC 3 – Blood cell sizes under the microscope

Method:

1. Set up a light microscope.
2. Place a mini grid slide on the stage and focus to low power.
3. Count the number of grids across the diameter of the field of view.
4. Focus on red blood cells under low power and estimate number to fit across field of view and so calculate size.
5. Turn to high power and do the same thing.
6. Repeat process for white blood cells.
7. Draw white and red blood cells to scale.

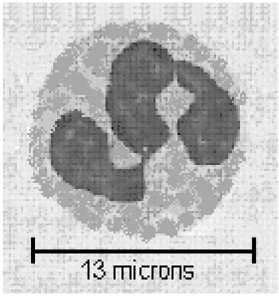
Results:

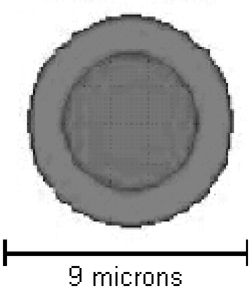
Red blood cells:

- Are about 7 microns in diameter
- Disc- shaped
- Transport oxygen
- No nuclei
- Live for three months before being destroyed in liver or spleen
- Produced in bone marrow

White blood cells:

- Are about 10 microns in diameter
- Irregular in shape
- Can change shape
- Contain an obvious nucleus.
- Defend against disease
- The largest blood cell
- Produced in the lymph glands





Technologies that allow measurement of oxygen saturation and carbon dioxide concentrations in blood

Arterial Blood Analysis:

Carbon dioxide from blood sample → diffuses through a gas-permeable membrane → causes an electrochemical reaction → causes a current → current generated is directly proportionate to oxygen concentration

Gives accurate readings, which can be very useful in indicating lung and heart disorders that would otherwise be difficult to identify and prevent.

Oxygen Saturation

A pulse oxmeter: measures the amount of oxygenated haemoglobin in the blood.

- It usually has a probe that attaches to the patients finger or ear lobe.
- It uses 2 wavelengths of light (red and infra-red).
- Oxygenated haemoglobin allow more red light to pass through and absorbs infra- red.
- Deoxygenated haemoglobin does the opposite
- It is used in monitoring oxygenation and pulse rates during anaesthesia during recovery phase, patients with severe breathing and heart problems and in intensive care during mechanical ventilation.
- It is cheap and simple to use, and is non-invasive
- May not be accurate if the person is suffering from severe hypotension, cardiac failure or a badly positioned part.

Carbon Dioxide Concentration

A capnomenter is an instrument incorporating an infra-red detector assembly, used to analyse CO_2 gases.

- Used in medical applications to monitor air exchange in the lungs of patients on ventilators or under anaesthesia.
- It can evaluate the respiratory condition of spontaneously breathing patients.
- It is used as it is non- invasive ad portable
- Can be used in home care and in general wards.

Products extracted from donated blood and their uses

Homologous: Whole blood- used for blood loss

Fresh frozen plasma: Liquid portion of blood. Often given in emergency to boost the volume of blood following severe blood loss. Because plasma carries dissolved nutrients it is important in the treatment of victims who lose a lot of blood.

White cell concentrate: Disease fighting. Given to patients needing a boost to their immune system, perhaps during or following a severe infection.

Platelet Concentrate: Essential for blood clotting. Patients with platelet disorders, cancer of the blood or lymph or severe blood loss.

Red blood cell concentration: Used to increase the oxygen carrying capacity. Given to people with anaemia, blood loss patients or those whose bone marrows don't make enough red blood cells. May also be used to help replace cells lost following significant bleeding.

Immunoglobins: Infection fighting part of the blood plasma. Used for people who have difficulty fighting infection and people whose immune systems don't work properly because of diseases such as AIDS.

Cryptoprecipitate: Collected from plasma- contains blood-clotting factors and is used to treat severe bleeding.

Factor VIII and Monofix: Extracts from plasma used to treat haemophilia.

Production and research of artificial blood and reasons why this research is needed

- The HIV crisis of the 1980's triggered research into artificial blood.
- There is a lack of donor supplies and a fear of contaminated (infected by hepatitis or HIV) blood supplies.
- Artificial blood can be sterilised to kill bacteria and viruses.
- Shelf life is over a year, compare to real blood, which is only 42 days refrigerated.

Artificial blood is currently only designed for:

- Increasing plasma volume- used in cases of severe burns
- Carrying oxygen- and carbon dioxide

No substitute has been developed that can replace other functions- coagulation and immune defence.

<u>Two types of oxygen-carrying artifical blood have been produced:</u>

1. **Perflurochemicals**- synthetic materials that can dissolve 50x more oxygen than blood plasma. Synthetic- no risk of disease. Cheap to produce. More research is needed because perflurochemicals must combine with other substances in order to mix in the blood stream, changing how well the blood can flow through blood vessels.

2. **Haemoglobin-based oxygen carriers-** made from haemoglobin extracted from red blood cells. Not contained in a membrane and therefore don't need blood typing. More research is required because haemoglobin must be modified before it can be used. Current blood substitutes do not have the enzymes that prevent haemoglobin from oxidising. When haemoglobin is oxidised it cannot carry oxygen.

Products to replace blood need to be:

- Immediately available
- Safe from disease
- Able to be stored for a long time (blood donor blood can only be stored for 3-4 weeks)
- Able to be used without blood typing and matching.
- Non-toxic
- Able to remain in circulation until the body is able to restore its own blood and then can be excreted without side effects

Such blood substitutes are useful in emergencies, disasters, wars and in countries where there are no blood donor services.

PRAC 4 – Use microscope to draw transverse and longitudinal sections of phloem and xylem.

1. Use scalpel to carefully cut the thinnest cross section and longitudinal section possible.

2. Mount the sections on microscope slides.

3. For the transverse section add a drop of iodine stain.

4. Add coverslips

5. Observe under high and low power.

6. Identify thick walled xylem cells in cross-section and their spiral thickenings in longitudinal.

7. Draw on a labelled diagram

8. Identify phloem cells in cross section and phloem sieve plates in longitudinal section

9. Examine prepared slides.

Three labelled diagrams:

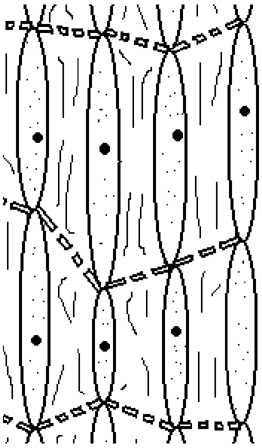
- Cross –section of celery stem

- Longitudinal Section vascular bundle

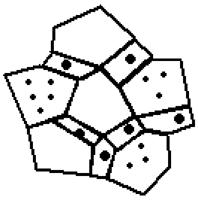
- Cross section prepared slide Vascular Bundle.

Phloem

Longitudinal



Transverse



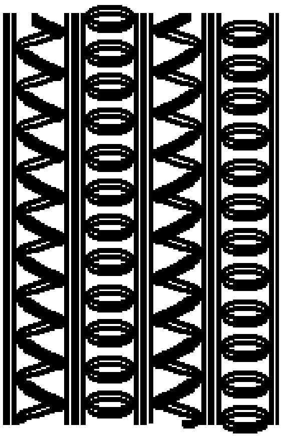
Sieve cells surrounded by companion cells

Cells are alive - nuclei present in companion cells

Sieve plates connect sieve tubes

Xylem

Longitudinal



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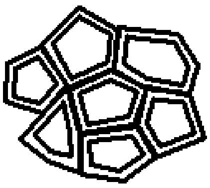


Thick walls

Lignified with rings or spirals

Cells are dead - no nucleus

3. PLANTS AND ANIMALS REGULATE THE CONCENTRATION OF GASES, WATER AND WASTE PRODUCTS OF METABOLSM IN CELLS AND INTERSTITIAL FLUID

Importance of water

Water is essential for life as it is the solvent in which substances are dissolved and carried in.

Water also regulates temperature- it can absorb or lose relatively large quantities of energy with minimal temperature change, helping stabilise the temperature of all living things.

Plants and animals rely on water for body support. Non woody plants pump their cell vacuoles full of water to make cells tight and keep stems upright. In vertebrate animals the water solutions in the tissues helps to cushion organs.

Cells work best in **ISOTONIC** (solute concentration is the same both inside and outside the cell) because they are sensitive to changes in solute concentrations & may lose or take in large amounts of water by osmosis if concentration externally changes, the cell dies.

Hypertonic: Concentration in cell lower than outside of cell.
Isotonic: Concentration equal
Hypotonic: Concentration in cell higher than outside

The removal of wastes

Due to all the metabolic processes occurring in cells, waste products such as salts, water, co2 and urea, are constantly formed. If they accumulate they would slow metabolism and poison cells. Ammonia (nitrogenous waste) is highly toxic so needs to be quickly removed and converted.

- Some are poisonous
- Some take up space
- Some would create problems for osmoregulation

The role of the kidney in the excretory system

The kidney has the role of excreting nitrogenous wastes and maintaining the water balance in mammals and fish. It is an organ of filtration, reabsorption and secretion.

Osmoregulation: Regulation of the water and salt concentrations in the water.

DEAMINATION

Amino acids are broken down in cell metabolism and ammonia is produced. Ammonia is extremely toxic, very soluble and diffuses readily across cells. In some fish it may diffuse out of gills and be excreted through the kidneys in dilute urine. In mammals, sharks and some bony fish it is converted to urea which is less toxic and can be stored briefly before being transported by the blood to the kidneys and excreted in urine.

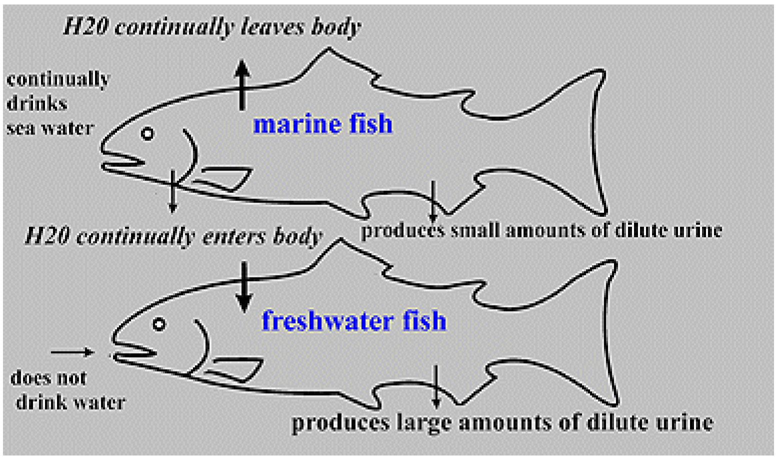
Freshwater Fish

Hypotonic. Higher concentration of solutes in body than out, so water diffuses into body so fish constantly needs to get rid of the excess. Produce lots of dilute urine. Do not drink. Gills excrete ammonia & co2 and actively absorb salts.

Saltwater Fish:

Hypertonic. Internal body fluids less concentrated than the surrounding water. To avoid water loss they keep drinking salt water- salts removed via gills and kidneys. Excrete small amounts of concentrated urine.

Mammals	Freshwater Fish	Saltwater Fish
Many nephrons	Simple- few small glomerus	Simple- many large Glomerulus
High blood pressure in Glomerulus	High filtration rate	Low filtration rate
Urine production depends on water intake	Large amounts of dilute urine	Small amounts of concentrated urine



The processes of diffusion and osmosis

Diffusion and osmosis are passive processes and will not occur unless a sufficient concentration gradient is present. The kidney removes nitrogenous wastes AGAINST concentration gradients. Diffusion and osmosis transport substances along with the concentration gradient, nit against.

These processes can also be quite slow. Large, active, multicellular animals quickly accumulate toxic levels of nitrogenous wastes and thus need other mechanisms using active transport.

- Diffusion is too slow and non-selective of solutes
- Osmosis would mean that waste would stay in the body and water would leave it.

Active and passive transport in the mammalian kidney

Active transport requires energy to undertake (movement against concentration gradient) whilst passive transport doesn't (materials follow the natural concentration gradient)

Active- Occurs in the movement of substances into the nephron and the selective reabsorption of glucose, vitamins, salts, minerals and amino acids from the nephron into the blood.

Passive- Occurs in the filtration of blood into Bowman's capsule and the osmotic movement of water back into the blood from the tubule in reabsorption.

Pressure in the Glomerulus causes water, ions and small molecules to filter into the Bowman's capsule. Reabsorption of glucose, amino acids and inorganic salts occurs by active transport. As these solutes move out of the nephric filtrate water follows by osmosis. Active transport of sodium ions causes more osmosis and the levels of salt and water are thus adjusted to maintain homeostasis.

Blood → Glomerulus → filtration → bowman's capsule → water, urea, glucose, salts, vitamins, amino acids, minerals, red and white blood cells → enter tubules and loop of Henle → selective reabsorption

Active & passive transport

Each nephron is made up of a Glomerulus and tubules. Blood flows into the nephron under pressure. As a result, plasma is forced through the glomerus into the Bowmans capsule.

The glomerus acts as a filter- particles in the blood such as blood cells and proteins are too large and don't pass into the Bowmans capsule.

The fluid that passes into the capsule moves along the tubules. Useful substances such as water, glucose and inorganic salts are reabsorbed in the loop and returned to the blood.

The amount of reabsorption, and therefore the composition and concentration of the urine, varies and changes with diet, exercise and metabolism.

In the tubules sodium is actively reabsorbed into **interstitial fluid** *(the fluid between the cells)***.** The wall of the collecting tubule may be permeable or impermeable to water.

If permeable, water is passively reabsorbed into the surrounding tissue. Concentrated urine is excreted and so water is conserved.

If impermeable, no water is reabsorbed and dilute urine is excreted.

The permeability of the wall of the collecting tubule to water is altered by vasopressin or antidiuretic hormone.

The processes of filtration and reabsorption in the mammalian nephron

The nephron is the functional and structural unit of the kidney, in which there are about 1 million nephrons, arranged in the outer cortex and central medulla

Filtration – reabsorption – secretion

Cortex: Blood is filtered and substances needed by body reabsorbed back into blood.

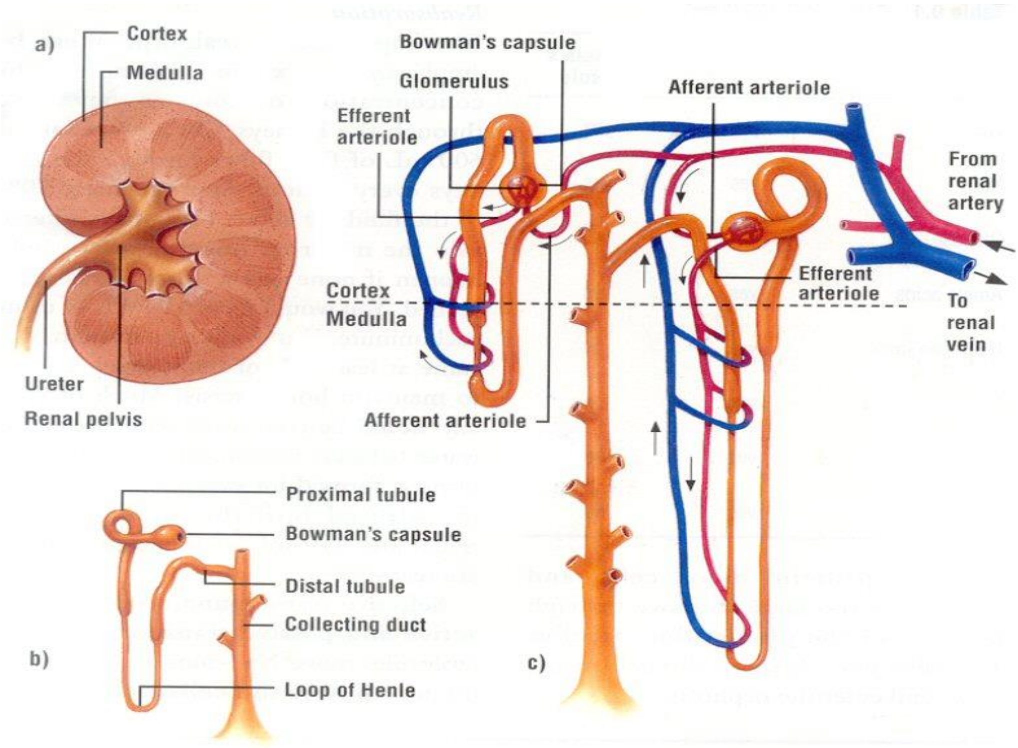
Pelvis: Urine passes down tiny tubes and collects here and then passes through the ureter to the bladder.

Medulla: Contains tubes that carry urine, water is reabsorbed back in to balance the concentration of the blood.

Renal Vein: Blood, which has been balanced, goes back to the heart.

Renal Artery: Blood comes from the heart to the kidney

Ureter: Urine passes down to the bladder.



1. **<u>BOWMANS CAPSULE- Filtration</u>**

Passive Transport

The renal artery splits into numerous arterioles, each feeding a nephron. The arteriole splits into numerous capillaries, which form a knot called a glomerus. The glomerus is enclosed by the Bowmans capsule.

There is high blood pressure in the capillaries of the Glomerulus. This pressure forces plasma out of the blood by filtration.

All molecules with a molecular mass under 70k are squeezed out of the blood to form a filtrate in the renal capsule. Only blood cells and large proteins remain in the blood.

2. **<u>PROXIMAL CONVOLUTED TUBULE- Reabsorption</u>**

Active & Passive Transport

Over 80% of the filtrate is reabsorbed into the tissue fluid and then to the blood. This ensures that all the 'useful' materials that were filtered out of the blood (glucose and amino acids) are now returned to the blood

Reabsorbed:

- Glucose
- Mineral ions (85%)
- Amino acids
- Small proteins
- Water (80%)
- Some urea

3. LOOP OF HENLE – formation of salt bath

Active transport of salt & passive transport of water

The purpose of this 'salt bath' is to reabsorb water. The loop of Henle does this by pumping sodium and chloride ions out of the filtrate into the tissue fluid. The first part of the loop (the descending limb) is impermeable to ions, but some water leaves by osmosis. The second part of the loop (the ascending loop) contains a pump, so ions are actively transported out of the filtrate into the surrounding tissue fluid. Water would follow by osmosis but it can't, because the ascending limb is impermeable to water, so the tissue fluid becomes more salty (hypertonic) and the filtrate becomes less salty (hypotonic).

4. DISTAL CONVOLUTED TUBULE – Homeostasis & Secretion (back into the tubule)

Active Transport

Certain substances are actively transported from the blood into the filtrate (secreted). It is regulated by hormones, so this is the homeostasis part of the kidney.

5. COLLECTING DUCT – Concentration

Passive transport

As the collecting duct passes through the hypertonic salt bath into the medulla, water leaves the filtrate by osmosis, so concentrating the urine and conserving water.

Controlled by the hormone ADH which opens the channels so more water is conserved in the body, and more concentrated urine is produced.

STRUCTURE	PROCESS	SUBSTANCES
Bowman's Capsule/Glomerulus	PASSIVE Filtration (pressure forces plasma out of the blood into the tubule)	All molecules small enough. Not red blood cells or large proteins
Proximinal Tubule	ACTIVE & PASSIVE 80% of filtrate reabsorbed back into the blood	Glucose, amino acids, vitamins, sodium, chloride, potassium, water, some urea
Loop of Henle	ACTIVE TRANSPORTS OF SALTS PASSIVE TRANSPORT OF WATER Formation of salt bath Reabsorption of water	Descending loop- water Ascending loop- salts
Distal Tubule	ACTIVE & PASSIVE TRANSPORT- WATER Reabsorption and secretion	Hydrogen ions (pH) Potassium ions (salt) Ethanol, toxins, drugs and other foreign substances
Collecting Duct	PASSIVE TRANSPORT Concentration	Water Urine formation

Role of hormones ADH and Aldosterone

Antidiuretic: Effect whereby urine production is decreased.
Aldosterone: Controls reabsorption of salt from nephron tubules.

	ALDOSTERONE	ADH OR VASOPRESSIN ANTIDURETIC HORMONE
Produced by	Adrenal gland above kidneys	Hypothalamus at base of brain
Acts on	Distal tubule and the collecting tubule	Collecting tubule only
Action	When sodium levels are low, aldosterone is released into the blood causing more sodium to pass from the nephron to the blood. Water then flows from the nephron into the blood by osmosis.	When fluid levels in the blood are low, ADH is released, increasing the permeability of the collecting tubule.
Result	Rise in blood volume and blood pressure	Rise in blood volume and blood pressure. Decreases urine volume.
Importance	More important when body fluids are lost, such as bleeding from an injury, when salt and water are both lost.	More important when the body is dehydrated, with insufficient water in the blood.
Role	*Stimulates nephron to decrease reabsorption of potassium and increase absorption of sodium in the blood.*	*Stimulates nephrons to reabsorb more water.*

ADH:

Released by pituitary gland (signals 'thirst' to brain) → causes more reabsorption of water from kidney tubules → body retains more water (less urine, more concentrated)

ALDOSTERONE:

Released by adrenal gland if salt levels are too low → active transport of more sodium ions back into the blood →chloride follows sodium so more salt is reabsorbed.

Enantiostasis and salt concentrations

Enantiostasis: The maintenance of metabolic and physiological functions in response to variations in the environment.

- Enantiostasis is particularly important for organisms living in an *estuarine* environment where salinity varies greatly, depending on factors such as tides and rainfall.

  Crabs & yabbies: Burrow into the mud, where the salt concentrations are more stable

- Trout, salmon and eels that *move from the ocean to rivers* must have adaptations to deal with salt and water problems experienced in both freshwater and marine environments.

  Eels: Have special cells in their gills that can act as salt absorbers and salt excretors.

- Mangroves have adaptations to cope with the salt water that covers their roots with every high tide.

Grey Mangrove:

- Leaves with thick, waxy cuticle.
- Salt glands on leaves excretes concentrated salt brine on leaves to be washed away with rain
- Salt is deposited in older leaves- when they drop off salt leaves plant
- Special tissues within roots allow water to pass through but filter salt.

Adaptations of Australian plants that assist in minimising water loss

- hard leathery, needle-shaped leaves with reduced surface areas and increase heat loss- *needlebush, acacia and coastal tea trees*
- Reflective leaves- *salt bush*
- Hanging their leaves vertically to present less surface area to sun- *eucalypts*
- Thick, waxy cuticle prevents evaporation- *Eucalypts*
- Deep extensive root systems below the watertable- *oleander*
- Thick bark prevents water loss through trunk
- Hairs on leaves shades leaf surface to prevent overheating from sun and reduces evaporation of water
- Sunken stomata reduce transpiration by humidifying the air directly above the stomata

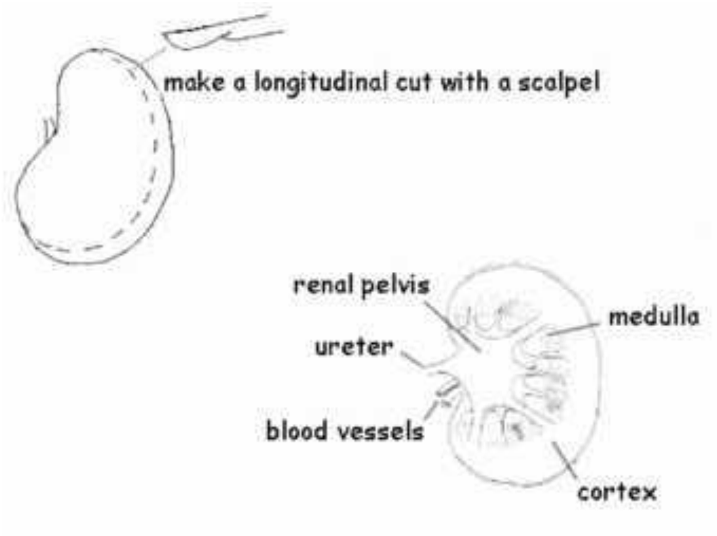
PRAC 5 – Kidney Dissection

Aim: To investigate the structure of the mammalian kidney and identify the regions involved in the excretion of waste products.

Method:

1. Use a scalpel to make longitudinal incisions through the soft, circular surface of the cortex.

The cortex, medulla, pelvis and ureter can be easily identified by their different colours and textures.



Renal Dialysis

Dialysis, meaning dissolution through loosening or splitting is a process for removing waste and excess water from the blood.

Feature	**Kidney**	**Renal Dialysis**
structure	Consists of about 1 million nephron that filter the blood. Renal pelvis and ureter.	Blood from an artery is pumped into a dialyser where it flows through tubes made of a selectively permeable membrane
Function and nitrogenous wastes	Removes urea	Removes urea
Other functions	Maintains blood pressure and concentration of water	Maintains concentration of ions in blood. Can be adjusted to suit the person
How often it occurs	Continuously	3-5 hours 3x a week
Filtration and reabsorption	Loop of Henle	doesn't

Two healthy kidneys filter the blood volume about once every half-hour. Dialysis is a much slower and less efficient process than the natural processes found in a healthy kidney but it is a lifesaver for those people with damaged kidneys.

Hormone replacement of aldosterone

Hormone replacement therapy refers to any form of hormone therapy wherein the patient receives hormones, either to supplement a lack of naturally occurring hormones, or to substitute other hormones for naturally occurring hormones.

The replacement hormone for aldosterone is called fludrocortisone. It is used to treat people with Addison's disease- caused by the destruction or shrinking of the adrenal cortex, which produces the two hormones cortisol and aldosterone. If the body cannot secrete aldosterone, water and salt balance cannot be maintained, and the volume of blood falls dangerously low, there is a drop in blood pressure and severe dehydration. When levels of both cortisol and aldosterone drop, many functions throughout the body are disrupted.

Comparison of the urine concentration of terrestrial mammals, marine fish and freshwater fish

Animal	*Urine Concentration*	*Reasons for the differences*
Terrestrial mammal	Concentration and volume varies – in desert mammals urine is highly concentrated, but in herbivorous mammals urine is less concentrated	Terrestrial organisms face the issue of conserving water and at the same time removing nitrogenous waste
Marine Fish	Highly concentrated	Aquatic organisms face the problem of osmosis. In seawater the concentrations of dissolved substances are usually lower in the body than in the environment. Water, therefore, tends to move out by osmosis and salts will diffuse in. Marine organisms excrete excess salt through the gills and very little urine is excreted. They drink large amounts of sea water to replace water loss.
Freshwater Fish	Dilute urine	In fresh water the concentrations of dissolved substances are usually higher in the body of the organism than its environment. Water, therefore, will tend to move into the organism by osmosis. The fish must rid themselves of the excess water, so excrete large amounts of dilute urine.

The relationship between the conservation of water and the production and excretion of concentrated nitrogenous wastes

Ammonia is very toxic and must be removed immediately, either by diffusion or in very dilute urine. It is the waste product of most aquatic animals. Ammonia is the immediate product of breakdown of amino acids. It is highly soluble in water and diffuses rapidly across the cell membrane. However, it needs large quantities of water to be constantly and safely removed.

Urea is toxic, but 10 000 times less toxic than ammonia, so it can be safely stored in the body for a limited time. It is the waste product of mammals, and some other terrestrial animals, but also of adult amphibians, sharks and some bony fish. It is made from amino acids but requires more steps and energy to make than does ammonia. It is highly soluble in water, but being less toxic than ammonia, it can be stored in a more concentrated solution and so requires less water to remove than ammonia. It is a source of water loss for these species.

Uric acid is less toxic than ammonia or urea, so can be safely stored in or on the body for extended periods of time. It is the waste product of terrestrial animals such as birds, many reptiles, insects and land snails. It is a more complex molecule than urea so it requires even more energy to produce. It is thousands of times less soluble than ammonia or urea and has low toxicity, which means that little water is expended to remove it. This is a great advantage for survival.

Terrestrial organisms face the problem of needing to conserve water while still getting rid of nitrogenous wastes in a form that is concentrated but not toxic.

Desert mammals:

- The red kangaroo produces highly concentrated urine.
- The mulgara, a small mouse like marsupial doesn't drink- moisture is provided in food and the large amounts of urea produced by a carnivorous diet are excreted in highly concentrated urine.
- The murid hopping mouse lives on dry seeds and has no drinking water and has the ability to produce concentrated urine.

Insects:

- Excretes excess nitrogen through the conversion of nitrogenous products into the almost insoluble substance called uric acid, which has low toxicity.
- Uric acid is excreted through special tubules or the deposition of uric acid crystals in various parts of the body.
- Almost no water is lost.

Processes used by different plants for salt regulation in saline environments

Plants in mangroves and coastal marshes live in the boundary between salt and fresh water, and use these three processes for keeping the growing stems and leaves mostly free of salt:

- **Salt Barriers:** Special tissues in the roots and lower stems stop salt from entering the plant but allow water uptake.

- **Secretion:** Some plants are able to concentrate salt and get rid of it through special glands on the leaves. Eg, the grey mangrove- the salt is then washed off by rain.

- **Salt deposits:** Some plants deposit salt in older tissues which are then discarded.

PRAC 6 – Observing plant structures assisting water conservation

Use a hand lens or binocular microscope to observe a range of plants such as acacia, Casuarina, Banksia, eucalyptus and hakea.

Structural adaptations such as waxy thick cuticles, hairy leaves, sunken stomata, reduced leaves to spines and needle like leaves can be observed.