IB BIOLOGY ESSAYS

List of Chapters (HL & SL)

1.1 Introduction to Cell

1. List the key statements of the cell theory.

- Living organisms are made up of one or more cells.
- There is no smaller unit of life than cells.
- Every new cell must come from a pre-existing cell.

2. Outline 3 exceptions to the cell theory.

- Giant algae can grow up to 10 cm in length for a single cell but only have 1 nucleus.
- Striated muscle cells are very long, up to 30 cm, and have multiple nuclei (multinucleate).
- Aseptate fungi hyphae have no cross walls and multiple nuclei.

3. State and define the 7 functions of life displayed by all living organisms.

- Metabolism is the sum of all chemical reactions within the living organism
- Reproduction is the production of offspring
- Homeostasis is the maintenance of the internal environment
- Nutrition is the consumption of materials for growth and repair. Nutrients are the source of energy or matter to build the organism
- Excretion is the removal of the waste products of metabolism
- Response is sensing and responding to external stimuli
- Growth is the increase in cell number or size

4. Explain how surface area to volume ratio limits the size of cells.

- The rate at which metabolic reactions occur increases as the cell volume increases.
- The rate at which raw materials enter the cell and waste materials exit increases as surface area increases.

- As the cell grows and size increases, the volume increases faster than surface area. Thus the surface area to volume ratio decreases.
- If a cell is too large, it cannot take in raw materials nor export waste products fast enough to function and it may overheat, thus a cell can only grow up to a certain size.

5. How does cell differentiation occur?

- Cell division ensures all cells in a multicellular organism are genetically identical, so every cell in the body has the full set of genes
- During the differentiation of a cell, only some of the genes are expressed, while others are not expressed.
- In each type of specialised cell, a unique subset of genes will be expressed.
- Gene expression results in proteins being synthesised which determines the function of the cell

6. Describe the characteristics of stem cells that make them potentially useful in medicine. [5m]

- Stem cells can continually divide to produce large numbers of identical cells. They can be used to replace or repair damaged cells.
- Stem cells are undifferentiated, thus have the ability to differentiate to produce a large variety of different tissues or organs. For example, skin stem cells can be grown to produce skin grafts for burn victims and pancreatic islet beta cells can be developed to treat type 1 diabetes

7. Describe Stargadt's disease and how stem cells can be used to treat it.

- Stargadt's disease is a genetic disease that causes macular degeneration in children and young adults. Photoreceptor cells in the retina become damaged and are progressively lost. Patients gradually lose their vision, usually resulting in blindness
- Embryonic stem cells can be used to treat Stargadt's disease. Scientists obtained stem cells from days-old human embryos and made them develop into retina cells. These cells were then injected into patients' eyes and helped improve vision

8. Describe Leukemia and how stem cells can be used to treat it.

- Leukemia is a type of cancer that causes a high number of abnormal white blood cells to be produced by the bone marrow
- Adult stem cells can be used to restore healthy bone marrow in leukemia patients. Fluid is taken from the patient's bone marrow. Healthy blood stem cells from the bone marrow or donor are identified and frozen. The patient receives a high dose of chemotherapy to kill all the cancer cells in the bone marrow. The bone marrow is then unable to produce any more blood cells. The stored or donated blood stem cells are injected into the patient and enter the bone marrow via the bloodstream. The bone marrow regains its ability to produce healthy blood cells.

9. What are the ethical implications of using embryonic stem cells for therapeutic uses?

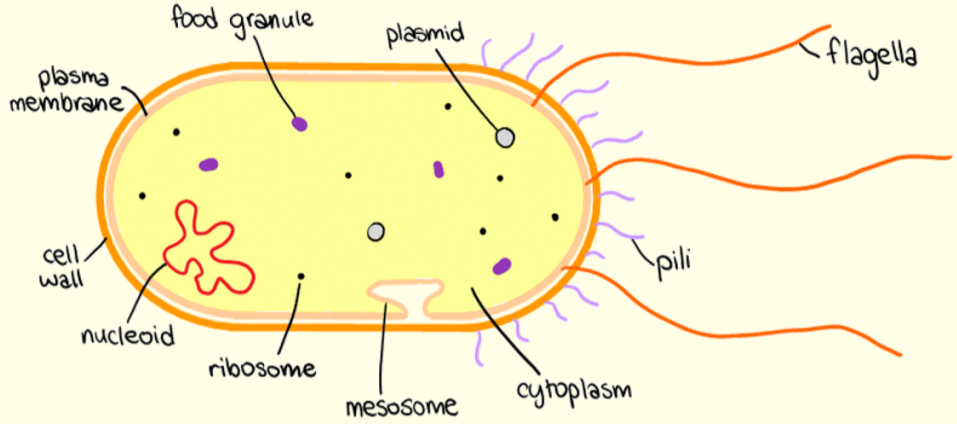
FOR	AGAINST
• Early-stage embryos are just groups of cells that have yet to develop essential features of life • Early-stage embryos lack a nervous system so do not feel pain or suffering • Large number of embryos produced during IVF are not used for implantation; better to use as stem cells to treat illnesses	• Embryo is human life at the earliest stage and is immoral if the embryo dies as a result of the procedure. • IVF involves invasive surgical treatment for removal of eggs • If women are paid for supplying eggs for IVF, could lead to exploitation of vulnerable groups of women

1.2 Ultrastructure of Cells

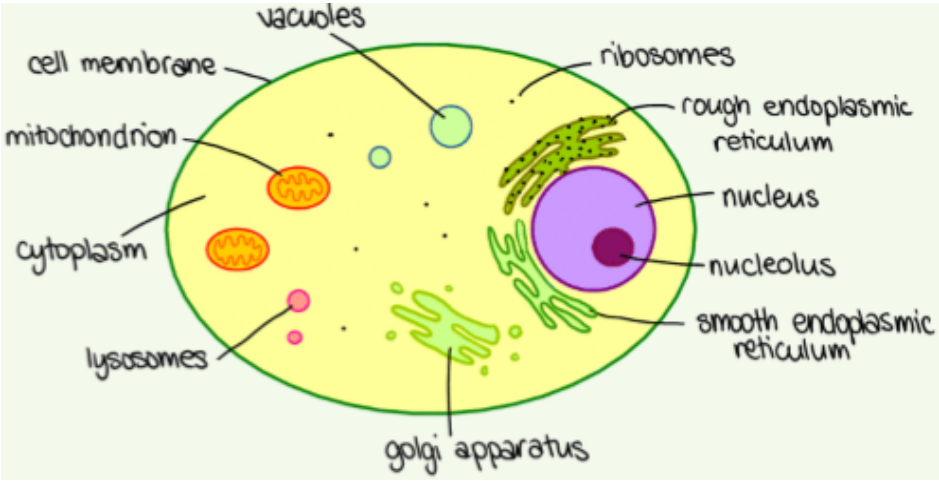
1. Define the term resolution. Distinguish the resolution of a light microscope (LM) and electron microscope (EM).

- Resolution is the smallest distance apart two objects can be to appear distinct.
- The resolution of an EM is much higher than a LM, at least 200 times higher. (1 nm compared to 200nm)

2. Draw a labelled diagram of Escherichia coli as an example of a prokaryote. [4m]



3. Draw a labelled diagram of a eukaryotic cell as seen in an electron micrograph. [4m]



4. Outline prokaryotic binary fission.

- The chromosome is replicated and each identical copy is moved to either end of the cell. The cell elongates.
- New cell wall forms and plasma membrane pinches in.
- Cross walls form 2 separate cells.
- The 2 new cells separate.

5. Outline the advantages of compartmentalisation in eukaryotic cells.

- Different metabolic processes can be separated. High concentrations of enzymes and substrates specific for each process can be achieved.
- Different metabolic processes may require different environments such as pH.
- These conditions can be optimised for each metabolic process while allowing both processes to occur in the same cell.
- Hydrolytic enzymes that can damage the cell can be separated (e.g lysozymes)
- Allows for a greater surface area for processes occurring within the cell membrane. For example, the production of ATP in the mitochondria via chemiosmosis.

1.3 Membrane Structure

1. Explain how phospholipids form a bilayer in an aqueous environment.

- Phospholipids are amphipathic - the phosphate head is hydrophilic and the fatty acid tails are hydrophobic. Thus, a phospholipid bilayer forms in water. The phosphate heads are attracted to the water, so are on the outside of the bilayer, in contact with the water.
- The fatty acid heads are repelled by water, thus face inwards of the bilayer, in contact with each other. The surface of the bilayer is hydrophilic and the inside of the bilayer is hydrophobic.

The chromosomes replicate and moves to either ends of the cell. The

2. Outline the evidence that led to the Davson-Danielli model.

- Chemical analysis of the membranes showed that they were composed of phospholipid and protein. Evidence suggested that the plasma membranes of red blood cells have enough phospholipids in them to form an area twice as large as the area of the plasma membrane, suggesting a phospholipid bilayer,
- Electron micrographs showed the plasma membrane as two dark bands on the outside and a light band in between, proteins appear very dark and phospholipids appear light. This supported the Davson-Danielli model.

3. Outline evidence for the falsification of the Davson-Danielli model.

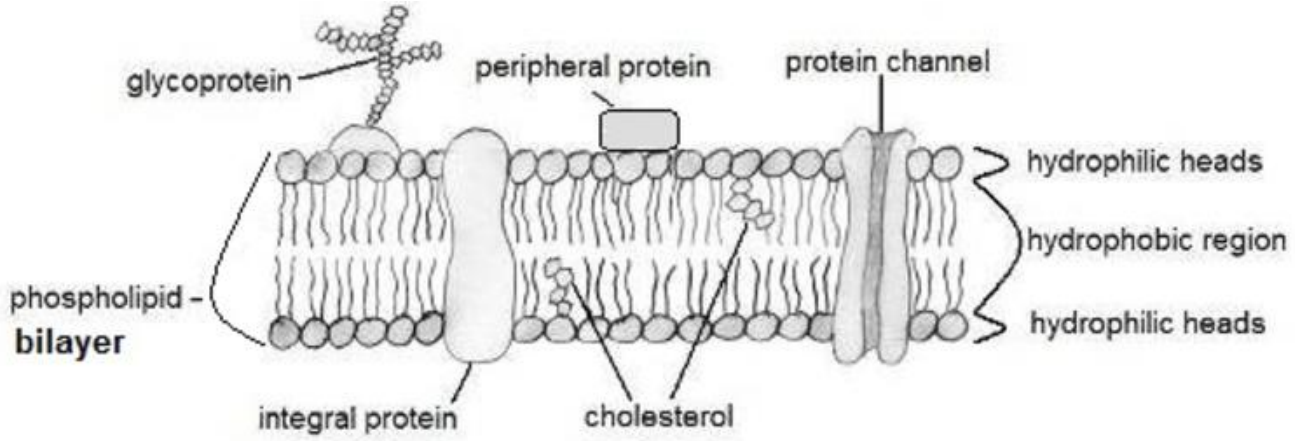
- Freeze fracture electron micrographs showed globular proteins present on the upper surface of the inner phospholipid layer.
- Proteins extracted from the plasma membrane were globular and varied in size and parts of their surface were hydrophobic, suggesting that proteins were embedded within the phospholipid bilayer and their hydrophobic regions could attract the fatty acid tails.
- This showed that proteins did not form layers on the surface of the plasma membrane.
- X-ray diffusion showed that at higher temperatures, the membrane behaved as liquid.
- Membrane proteins of two cells were linked to two different coloured fluorescent labels. The two cells were fused. Initially, the newly formed cells had 2 distinct regions of colour. After a short time, the two different colours were fully mixed. These findings demonstrated that phospholipids and proteins were free to move within the membrane.

4. Discuss alternative models of membrane structure including evidence for or against each model. [8m]

- Early evidence showed membranes are partially permeable and organic solvents penetrate faster than water, suggesting they have non-polar regions. Chemical analysis showed that membranes mainly consist of proteins and lipids.
- Phospholipids orientate themselves into a bilayer in water, their hydrophobic fatty acid tails facing away from water and their hydrophilic phosphate heads facing towards water.
- Evidence from electron microscopy supported the Davson-Danielli model which proposed phospholipid bilayer coated with protein molecules on both surfaces. Micrographs showed a three-layered structure, two dark bands with a light band in between, suggesting the Davson-Danielli model.

- Fluorescent labelling and freeze-fracture later used to investigate membrane structure falsified the Davson-Danielli model and led to the Singer-Nicholson model which showed a fluid mosaic model of protein models floating in a fluid lipid bilayer. It showed particles and proteins project partially and sometimes right through the lipid bilayer.

5. Draw a labelled diagram to show the molecular structure of the plasma membrane. [5m]



6. Outline the positions and functions of proteins in membranes. [8m]

- Integral proteins are embedded in the membrane while peripheral proteins are on the surface of the membrane. Some proteins are transmembrane proteins that extend from one side of the membrane to the other.
- Hormone binding sites: e.g. insulin, enzymes
- Cell adhesion: e.g tight junctions
- Cell-to-cell communication: e.g. antigens in ABO blood groups
- Transport proteins:
    - E.g. Channels / pores for passive transport
    - E.g. Pump proteins for active transport

- Receptors for neurotransmitters; e.g. acetylcholine
- Electron carriers: e.g. electron transport chain of cellular respiration

7. State the role of cholesterol in animal cell membranes.

Cholesterol reduces membrane fluidity which increases its stability. This reduces the membrane fluidity to some substances, generating differences in concentrations of ions across membranes.

8. Explain the partial permeability of the phospholipid bilayer.

- To move through the phospholipid bilayer, substances pass via gaps between the phospholipids, which is dependent on their size and charge. The inside of the phospholipid bilayer is hydrophobic and non-polar due to the fatty acid tails. Thus, small, non-polar molecules such as oxygen and carbon dioxide are able to pass through. Fatty acids and lipid-soluble molecules can pass freely through as they are non-polar.
- Hydrophilic substances include polar molecules and ions. Small polar molecules, such as water or urea, can pass through slowly. Large polar molecules, such as glucose and amino acids, cannot pass. Ions such as H^+ and Cl^- are charged and cannot pass.

1.4 Membrane Transport

1. Outline four types of membrane transport, including their use of energy. [4m]

- Simple diffusion is the passive movement of molecules down a concentration gradient
- Facilitated diffusion is the passive movement of molecules along a concentration gradient through a protein channel
- Osmosis is the passage of water through a membrane from lower to higher solute concentration
- Active transport is the movement of molecules against the concentration gradient, through membrane pumps with the expenditure of energy from ATP
- Endocytosis is the formation of vesicles to bring molecules into the cell with the use of energy

2. Outline the effects of placing red blood cells in a hypertonic, isotonic, and hypotonic solution.

- A hypertonic solution has a higher solute concentration than the tissues, thus water moves out of the cells, from lower solute concentration to higher solute concentration via osmosis.
- An isotonic solution has the same solute concentration as the tissues, so there is no net movement of water via osmosis in and out of the cells.
- A hypotonic solution has a lower solute concentration than the tissues, thus water moves into the cells via osmosis. The red blood cells will eventually burst.

3. Outline the reasons why organs for transplantation need to be bathed in isotonic solutions when outside of a body.

Isotonic solutions have the same solute concentration as the cells of the organ. This avoids the cells shrinking or swelling and even bursting due to the net movement of water via osmosis.

4. Define osmolarity.

Osmolarity is defined as the measure of solute concentration, the number of moles of solute per liter of solution. (osmol/L)

5. Outline active transport, including the benefits of the process.

- Active transport is the movement of substances against a concentration gradient, which requires energy from ATP and involves protein pumps.
- This is beneficial as it allows for the absorption of substances such as nutrients into a cell even if exterior concentrations are very low. Protein pumps are also unidirectional as they only transport substances in one direction. It also allows a concentration gradient to be generated or membrane potential, such as resting potential.

6. Outline endocytosis and exocytosis

- During endocytosis, the plasma membrane engulfs molecules due to the fluidity of the membrane which invaginates. The membrane pinches off on the inside, forming a vesicle containing materials from outside the cell. The vesicle breaks away from the plasma membrane and moves into the cytoplasm. This is an active process as it requires energy. For example, phagocytosis and pinocytosis.
- During exocytosis, vesicles carry materials to the plasma membrane. The vesicles fuse with the membrane by joining phospholipid bilayers, due to the fluidity of the membrane. Materials within the vesicle are secreted outside the cell. The membrane of the vesicle is now part of the plasma membrane. For example, exocytosis of neurotransmitters into the synaptic cleft.

1.5 The Origin of Cells

1. Pasteur's experiments using swan-necked flasks demonstrated that spontaneous generation does not occur. Describe how the evidence from his experiments led him to this conclusion.

Pasteur used swan-necked flasks as they prevented the entry of airborne organisms into the flasks. In his into the flasks. In his first experiment, he used regular flasks and sterile broth as a control, to show that microbes grew in the broth. In the second experiment, he used swan-necked flasks and sterile broth to show that microbes did not grow. In the third experiment, he snapped the necks of the flasks and microbes grew. Pasteur concluded that spontaneous generation did not occur and microbes grew in the broth only if the neck of the flask allowed airborne organisms to fall into the broth.

2. Outline the endosymbiotic theory and the evidence which supports it.

The endosymbiotic theory explains the origins of eukaryotic cells. It asserts that eukaryotes evolved from prokaryotes, which engulfed other prokaryotes without digesting them. For example, an engulfed aerobic cell evolved to become mitochondria while an engulfed photosynthetic cell evolved to become chloroplasts. These organelles have a double membrane due to the endocytosis process. Mitochondria and chloroplasts also have their own circular genome comprising naked DNA, divide by binary fission, and have ribosomes that are more similar to 70S than 80S ribosomes, which are all characteristic of prokaryotic cells.

1.6 Cell Division

1. Define the cell cycle and outline its various stages.

The cell cycle comprises the events that take place between the formation of a cell and when it divides. The stages of the cell cycle include interphase, mitosis, and cytokinesis. Interphase is further divided into the G1 phase, S phase, and G2 phase.

2. Outline the events that take place during the three phases of interphase.

- During the G1 phase, cell activities include translation, transcription, cell differentiation, cellular respiration, and synthesis of new organelles
- During the S phase, DNA replication occurs to ensure that a new cell formed had a full set of chromosomes.
- During the G2 phase, the cell prepares further for nuclear division. Chromosomes begin condensing and centrioles replicate in animal cells.

3. Define mitosis and outline its various stages.

Mitosis is a type of nuclear division in eukaryotic cells, to produce two genetically identical daughter nuclei. The four stages of mitosis are prophase, metaphase, anaphase, and telophase.

4. Outline the events that take place during the four phases of mitosis. [6m]

- During prophase, chromosomes supercoil and condense. Centrioles move towards opposite poles and spindle microtubules form. The nuclear membrane starts to break down.
- During metaphase, the centrioles are at opposite poles of the cell and the nuclear membrane is fully broken down. The chromosomes are fully condensed. Spindle microtubules attach to the centromere of each chromosome. One spindle microtubule from each centriole attaches to each side of a centromere. Chromosomes line up at the equator of the cell.
- During anaphase, the centromeres divide and the two sister chromatids are separated. The spindle microtubules shorten, pulling genetically identical chromosomes to each pole. At the end of anaphase, each pole has an identical set of chromosomes.

- During telophase, the chromosomes at each pole uncoil and a nuclear membrane forms around the two sets of chromosomes. The spindle microtubules form.

5. Describe what happens to the membranes of an animal cell during mitosis. [2m]

In prophase, the nuclear membrane breaks down, then reforms around two new genetically identical nuclei during telophase. The membrane pinches apart to form 2 cells, dividing the cytoplasm during cytokinesis.

6. Outline the structure and functions of nucleosomes. [4m]

- Nucleosomes are found in eukaryotes. They consist of DNA wrapped around 8 histones which are held together by other histones. They function to supercoil chromosomes and facilitate DNA packing. They regulate transcription and gene expression.

7. What is cytokinesis and how does it differ in animal and plant cells?

- Cytokinesis is the division of the cytoplasm. It occurs at the end of mitosis and results in two separate daughter cells being produced.
- In animal cells, the plasma membrane pinches in all the way around the equator of the cell. When the membrane meets the middle of the cell, the cell splits to form two identical cells.
- In plant cells, a line of vesicles forms at the equator of the cell, which joins together to form plasma membranes and cell walls, separating the 2 daughter cells.

8. What are cyclins and how were they discovered?

- Cyclins are proteins that control and coordinate the different phases of the cell cycle. They make sure one phase of the cell cycle only starts when another is complete and stops the progression of the cell cycle if the cell should not divide. Cyclins pair with cyclin-dependent kinases (Cdks) to regulate the activity of other proteins that carry out other phase-specific roles.

- Cyclins were discovered by serendipity. Researchers studying protein synthesis in sea urchins noticed that the levels of some proteins increased and decreased in regular cycles, coinciding with the cell cycle. These proteins were named cyclins and found to have a key role in the control and coordination of the cell cycle.

9. Outline the relationship between the concentration of cyclins and the progression of the cell cycle.

Phase transitions coincide with high levels of each cyclin. The cyclins must reach a threshold level for the cell cycle to progress. For example, a high concentration of cyclin A coordinates the transition from S phase to G2 phase. The level of Cdk remains constant.

10. Define the words 'mutagen', 'oncogenes', 'primary tumour', 'secondary tumour' and 'metastasis'

- A mutagen is an agent that causes changes in the DNA sequence, such as chemical substances and ionising radiation.
- oncogenes normally code for proteins that prevent the development of tumours. some oncogenes code for proteins that control the cell cycle, such as cycling. Mutations in oncogenes may result in their loss of function. This causes cells to keep dividing when they should not which results in a tumour.
- A primary tumour is formed when a cell that has lost its ability to control the cell cycle keeps dividing to produce a mass of cells. They can be benign or malignant, which causes cancer.
- Metastasis is the spread of cells from a malignant tumour to a different part of the body.
- A secondary tumour is formed from the cells that have metastasised (spread).

2.1 Molecules to Metabolism

1. What is the theory of vitalism and how was it falsified?

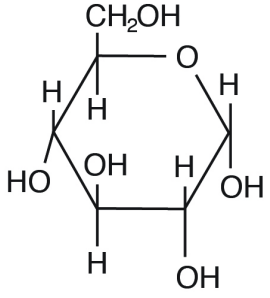
- The theory of vitalism is that a 'vital force' is needed to make organic compounds. A vital force was thought to act in addition to the scientific laws that govern the chemical reactions of non-living materials.
- The theory of vitalism was falsified by the synthesis of the organic compound urea by Friedrich Wohler in 1828. In humans, urea is synthesised in the liver and is produced when excess amino acids are broken down. Urea is a type of nitrogenous waste. It is filtered from the blood by the kidneys and is a component of urine. Following Wohler's breakthrough, other scientists synthesised different

organic compounds from inorganic compounds and pure elements, falsifying the theory of vitalism.

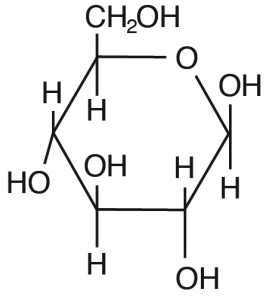
2. State the role of four named minerals needed by living organisms. [4m]

- Sulfur is a mineral that makes up amino acids and proteins
- Calcium plays a role in the formation of bones, muscle contraction and synaptic transmission
- Iron plays a role in the formation of haemoglobin and transport of oxygen
- Sodium plays a role in nerve impulses and sodium-potassium pumps

3. Draw molecular diagrams of alpha-D glucose and beta-D glucose.



alpha-glucose

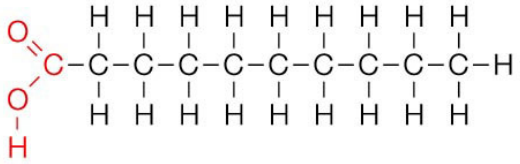


beta-glucose

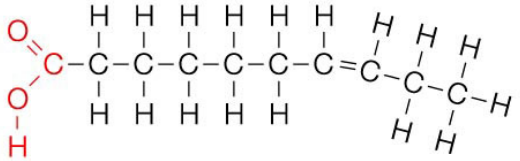
4. Draw molecular diagrams of (i) saturated & unsaturated fatty acid (ii) amino acid (iii) ribose & deoxyribose

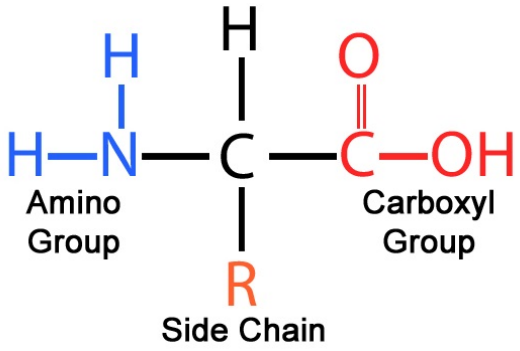
(i) fatty acids	(ii) amino acid	(iii) ribose & deoxyribose

Saturated

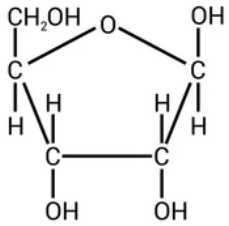


Unsaturated

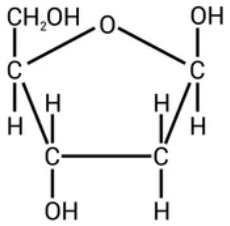




Ribose



Deoxyribose



5. Outline the term metabolism.

Metabolism is the sum of the enzyme catalysed reactions that occur in an organism. Some reactions are linked in a sequence and they are called metabolic pathways, which can be linear or cyclical. Different metabolic pathways link together to make a large network of interconnected reactions, each catalysed by an enzyme. Reactions occur in the cytoplasm, in organelles, and outside of the cell. Metabolism is subdivided into anabolism and catabolism.

6. Outline anabolism and catabolism, providing examples.

- Anabolism is the build-up of small molecules to form larger molecules. For example, condensation reactions join monomers to form polymers, such as the synthesis of starch from glucose.
- Catabolism is the breakdown of large molecules into smaller molecules. For example, hydrolytic reactions such as digesting

polypeptides to form amino acids.

2.2 Water

1. Outline how hydrogen bonds form in water. [3m]

Water molecules are polar and have partially positive and negative poles. Hydrogen bonds are formed due to the attraction between positive and negative poles of water molecules. Intermolecular hydrogen bonds can be formed between the hydrogen and oxygen atoms of different water molecules.

2. Explain the cohesive property of water and give one example of how it enables life.

Water is cohesive as molecules are able to attract each other due to their dipolarity and the formation of hydrogen bonds. For example, in the transpiration stream. Cohesive properties of water in xylem vessels allow long, continuous columns of water to be pulled up the plant stem under tension.

3. Explain the adhesive property of water and give one example of how it enables life.

Water is adhesive as molecules are able to be attracted to hydrophilic surfaces of other polar molecules, due to their dipolarity. For example, in generating the transpiration pull. As water evaporates from mesophyll cells and into air spaces within the lead, adhesion between water molecules and the cellulose cell walls of lead mesophyll cells pulls water from the xylem to replace the lost water.

4. Explain the thermal property of water and give an example of how it enables life.

- Water has a high specific heat capacity as a large amount of energy is required to increase the temperature of water, due to the presence of hydrogen bonds which limits the movement of water molecules, allowing water to maintain a steady temperature. For example, the internal temperature of larger organisms remains fairly constant when outside temperatures change.
- Water has a high latent heat of vaporisation as a large amount of heat energy is required to break the hydrogen bonds for water to

evaporate. For example, evaporation of water from sweat on the skin causes cooling.
- Water has a high boiling point (100°C) as hydrogen bonds must be broken to change from liquid to gas. Thus, it exists as a liquid in most places on Earth. For example, water makes up between 65-95% of all organisms, making water a suitable medium for life.

5. Explain the solvent property of water and give one example of how it enables life.

Water is a polar solvent due to the dipolarity of each water molecule. Polar molecules have polar groups (-OH and -NH), thus are soluble in water as they form hydrogen bonds with water molecules. Ions are positively charged or negatively charged, thus they are attracted to the oppositely-charged region of the water molecules. For example, water is a transport medium as many dissolved substances such as glucose and amino acids are transported in blood.

2.3 Carbohydrates and Lipids

1. Outline the general features of carbohydrates.

Carbohydrates are organic molecules composed of one or more monosaccharides. They include sugars and polysaccharides. Sugars include monosaccharides e.g. glucose and fructose, and disaccharides e.g. maltose and sucrose. Sugars are small, soluble molecules which are the most important source of energy for many cells. Monosaccharides can be added to form polysaccharides, e.g. starch, glycogen and cellulose. Polysaccharides are large, complex molecules that are insoluble.

2. Outline the formation of maltose, lactose and sucrose using word equations.

- Glucose + Glucose → Maltose + Water
- Glucose + Galactose → Lactose + Water
- Glucose + Fructose → Sucrose + Water

3. Describe the structure of amylose and amylopectin.

- Amylose is a chain of alpha-glucose monomers joined by 1,4 glycosidic bonds which is unbranched. The long chains of alpha-glucose monomers forms a helix
- Amylopectin is a chain of alpha-glucose monomers joined by 1,4 glycosidic bonds and some 1,6 glycosidic bonds, which is branched.

4. Explain how the structure of starch is related to its function.

The function of starch is to store glucose. Starch is a very large molecule, so it is insoluble. This means starch does not cause water to move into cells where it is stored. The helix is a compact structure that enables storage. The branched structure of amylopectin means it has many ends. This allows starch to be more rapidly made or broken down.

5. Describe the structure of glycogen and explain how it is related to its function.

- Glycogen is made up of a chain of alpha-glucose monomers joined by 1,4 glycosidic bonds and 1,6 glycosidic bonds. There are more 1,6 glycosidic bonds than there are in amylopectin, hence it is more highly branched.
- Glycogen is a large and compact store of glucose in mammalian muscle and liver cells. It is insoluble so it will not allow water to move into cells where it is stored. More branches allow glycogen to be broken down very rapidly, to supply glucose for cell respiration.

6. Describe the structure of cellulose and explain how it is related to its function.

- Cellulose is a chain of beta-glucose monomers joined by 1,4 glycosidic bonds, and it is unbranched. Due to the position of the -OH on carbon 1 in beta-glucose, every other glucose monomer must be rotated 180^{o} to form 1,4 glycosidic bonds. The long chain of beta-glucose monomers is straight rather than a helix.
- The function of cellulose is to help provide mechanical support in plants. Groups of long, straight cellulose molecules can line up close to each other. This allows many hydrogen bonds to form between the polar -OH groups in neighbouring molecules. Cellulose molecules associate to form strong microfibrils which have great mechanical strength and form the cell wall of plant cells.

7. Name and describe the three main types of lipids.

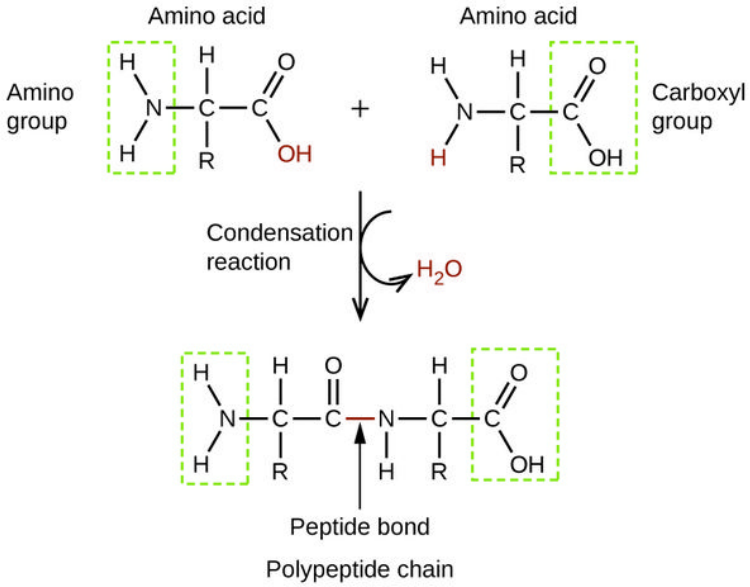
- Triglycerides are composed of one glycerol and three fatty acids, joined by condensation reactions. E.g. fats and oils. They are hydrophobic.
- Phospholipids are composed of one phosphate group, one glycerol, and 2 fatty acids. They form the phospholipid bilayer of membranes and are amphipathic.
- Steroids contain co-joined C-rings in their structure, including cholesterol and male and female sex hormones.

8. What are the advantages of lipids over carbohydrates as long terms stores of energy?

- Carbohydrates are found in the form of glycogen, stored in liver and muscle cells. Lipids are found in the form of triglycerides, stored in adipose tissue
- Lipids release approximately twice the amount of energy per gram compared to carbohydrates. Lipids can store an equivalent amount of energy for less storage space. Lipids are able to store more than 6 times as much energy per gram of body mass. They enable organisms to transport large energy stores in a small mass.

2.4 Proteins

1. Draw a molecular diagram to show the formation of a peptide bond. [3m]



2. State the 6 functions of proteins, giving an example for each.

- Enzymes - e.g. Rubisco catalyse the fixation of inorganic carbon dioxide from the atmosphere into carbon compounds, this is the first major step in the production of organic compounds by photosynthesis.
- Hormones - e.g. Insulin is a hormone that is secreted by the pancreas and transported in the blood. It regulates blood glucose levels
- Antibodies - e.g. Immunoglobulins destroy pathogens and are produced as part of the specific immune response
- Pigments - e.g. Rhodopsin is a light-sensitive pigment present in rods, a type of photoreceptor
- Structural function
    - E.g. Collagen is a protein made of 3 polypeptide chains twisted around each other. It is strong and flexible and used in ligaments, tendons and blood vessels.
    - E.g Spider silk can stretch without breaking

3. Distinguish between fibrous and globular proteins with reference to an example each. [6m]

- Fibrous proteins are strands or sheets while globular proteins are rounded.
- Fibrous proteins are usually insoluble while globular proteins are soluble.
- Fibrous proteins are less sensitive to changes in pH or temperature than globular proteins.
- Fibrous proteins have structural roles e.g. collagen, fibrin, spider silk, while globular proteins are used for catalysis or transport e.g. haemoglobin, lysosyme

4. Define the term 'proteome'. Why do all individuals have a unique proteome?

- The proteome is all the proteins produced by a cell, tissue, or individual
- Proteins are coded by genes. Any genetic differences between individuals will result in them coding slightly different proteins. Hence, a different genome will lead to a different proteome. In addition, the proteome can change during development or in response to environmental factors.

5. Outline the four levels of protein structure.

- The primary structure of proteins is the sequence of amino acids in the molecule. Proteins differ in the variety, number, and order of their amino acids. The primary structure determines the shape and structure of the protein.
- The secondary structure develops when parts of the polypeptide chain take up a particular shape by coiling to produce an alpha helix or folding into beta-sheets
- The tertiary structure is a precise, compact structure, unique to a particular protein. The molecule is further folded and held in a complex shape, made permanent by 4 different types of bonds (disulfide bridges, hydrogen bonds, ionic bonds, and hydrophobic interactions) that are established between adjacent parts of the chain. Some form into long, coiled chains (fibrous proteins) while others take up a spherical shape (globular proteins).
- The quarternary structure is formed when 2 or more proteins are held together, forming a complex, biologically active molecule e.g. haemoglobin.

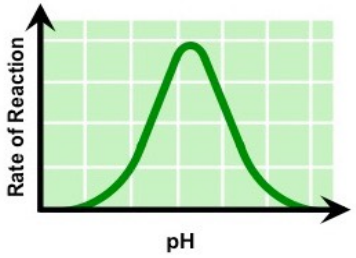
2.5 Enzymes

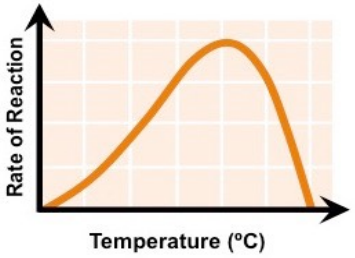
1. Outline the action of enzymes. [4m]

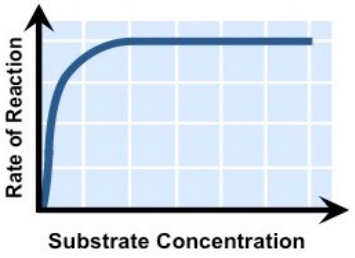
Enzymes are biological catalysts, they speed up chemical reactions by lowering the activation energy, providing an alternate pathway for the reaction to take place. Enzymes are substrate specific, only the correct substrate can fit onto the active site, forming an enzyme-substrate complex.

2. Explain the effect of (i) substrate concentration, (ii) temperature, and (iii) pH on enzyme activity.

- Increasing substrate concentration causes more frequent collisions between the substrate and the active site of the enzyme, increasing enzyme activity. At a certain substrate concentration, maximum enzyme activity is reached and it reaches a plateau.
- Increasing temperature causes enzyme and substrate molecules to possess more kinetic energy. As such, more frequent collisions occur and enzyme activity doubles every 10°C increase. The optimum temperature is the maximum enzyme activity. As temperature increases past optimum, the vibrations in the enzyme molecule increase, causing intramolecular interactions between non-adjacent amino acids to break. This causes the active site to be altered and the substrate can no longer bind to the active site. Thus the enzyme is denatured.
- At optimum pH, enzyme activity is maximum. Deviations from optimum pH cause enzyme activity to decrease. Large changes in pH can cause intramolecular interactions between non-adjacent amino acids to break. This causes the active site to be altered and the substrate can no longer bind to the active site. Thus the enzyme is denatured.







3. Outline the production of lactose-free milk and its advantages. [6m]

- Lactose is a disaccharide found in milk. Lactase is an enzyme that catalyses the hydrolysis of lactose to glucose and galactose. Lactase can be purified from microorganisms that live in yeast.
- Method 1: Lactase is added to milk to reduce the level of lactose in the milk
- Method 2: Lactase can be immobilised in alginate beads. Many beads can then be placed into a syringe barrel to form a column of beads. Milk flows through the column at a controlled rate to produce lactose-free milk.
- Some people are lactose intolerant, so lactose-free milk allows them to consume milk without bloating.
- Milk containing glucose and galactose is sweeter, so less sugar is required for lactose-free milk products.

8.1 Metabolism

1. Outline the control of metabolic pathways by end-product inhibition. [5m]

End-product inhibition involves the end product of the pathway (e.g. isoleucine) inhibiting the enzyme (e.g. threonine deaminase) catalysing the first step of a metabolic pathway. The end product is a non-competitive inhibitor and it binds to an allosteric site on the enzyme, reducing its activity. This mechanism controls the concentration of the end product. If the end-product accumulates, it will inhibit its own production. If the concentration of the end-product is low, inhibition is reduced, and production increases. End-product inhibition also avoids the build-up of intermediates. It is an example of negative feedback.

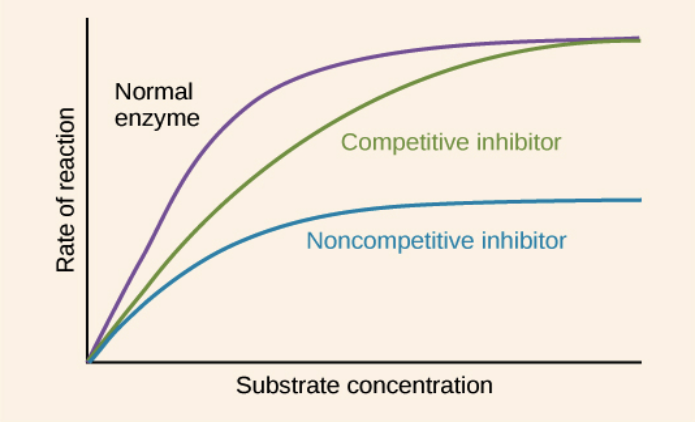
2. Explain the effect of inhibitors on the activity of enzymes and distinguish between competitive and non-competitive inhibitors. [8m]

- Enzyme inhibitors are substances that bind to enzymes and lower their activity. The binding of inhibitors may be reversible or irreversible. There are competitive and non-competitive inhibitors.

<u>Competitive inhibitors</u>	<u>Non-competitive inhibitors</u>
• Have a similar structure to substrate • Binds to active site • Prevents substrate binding as binding blocks active site	• Different shape as substrate • Binds to allosteric site • Reduces substrate binding as binding causes active site to change shape • Increasing substrate concentration has no effect on non-competitive

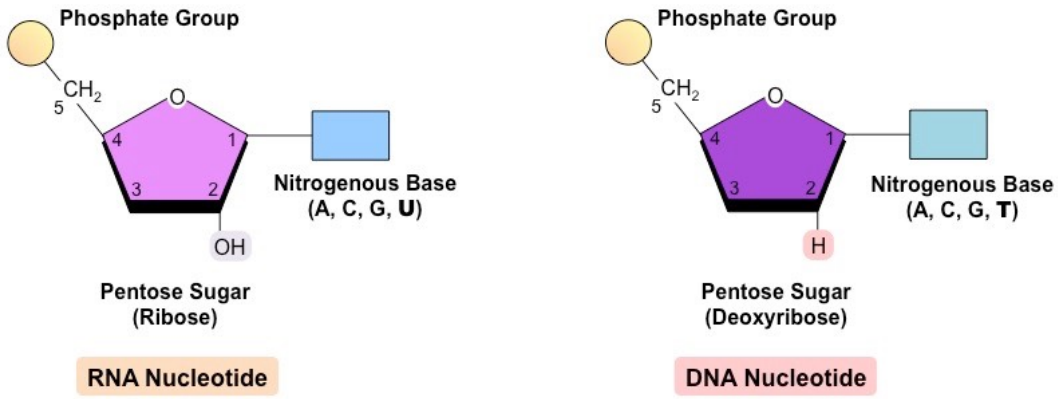
• Increasing substrate concentration reduces the effect of competitive inhibitor • E.g. Malonate inhibits succinate dehydrogenase	inhibitors • E.g. cyanide is a non-competitive inhibitor of cytochrome oxidase (electron transport chain)

3. Draw a graph to show the effect of a fixed concentration of competitive and non-competitive inhibitors on an enzyme-catalysed reaction at increasing substrate concentration.

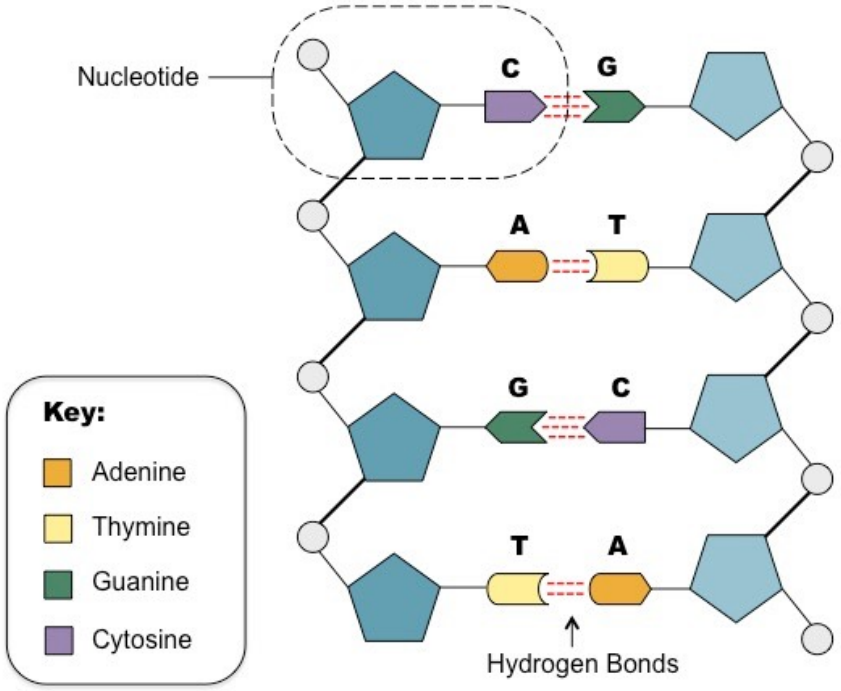


2.6 Structure of DNA & RNA

1. Draw and label a DNA and RNA nucleotide.



2. Draw the structure of a section of DNA, showing all possible nucleotides. [5m]



3. Outline the structure of a DNA molecule.

DNA molecules are double-stranded. The 2 DNA strands are connected by hydrogen bonds with guanine, which are complementary base pairs. Each DNA strand is the complementary sequence of the other. The DNA strands are twisted into a double helix, the sugar and phosphate groups on the outside of the molecule and the nitrogenous bases on the inside of the molecule.

4. Distinguish between the structures of DNA and RNA. [3m]

DNA	RNA
• Double-stranded • Pentose sugar is deoxyribose • Consists of adenine, guanine, thymine, and cytosine	• Single-stranded • Pentose sugar is ribose • Consists of adenine, guanine, uracil, and cytosine

2.7 DNA Replication, Transcription, and Translation (SL)

1. Outline the process of DNA replication.

Helicase unwinds the DNA double helix, breaking up the hydrogen bonds, separating the two strands of the DNA molecule. Each strand acts as a template. Free DNA nucleotides pair up with their complementary bases in each template strand (AT - CG). DNA polymerase forms each new strand by joining nucleotides together with covalent bonds between the sugar and phosphate. Two identical DNA molecules are formed.

2. Describe the process of transcription

RNA polymerase binds to the DNA double helix at the start of the gene. RNA polymerase unwinds the double helix, breaking hydrogen bonds and separating the 2 strands of the DNA molecule. One strand, the antisense strand, acts as the template strand. Free RNA nucleotides pair up with their complementary bases in the template strand. Uracil replaces thymine and pairs up with adenine, cytosine pairs up with guanine. RNA polymerase forms the mRNA molecule by joining the RNA nucleotides with covalent bonds between the sugar and phosphate. As RNA polymerase moves down the gene, the growing mRNA molecule separates from the template strand and the DNA strands re-join and then twist into a helix. RNA polymerase reaches the end of the gene and releases the mRNA strand.

3. What is the genetic code?

The genetic code is a triplet code, which means that one amino acid is coded for by three nucleotides. There are 64 possible combinations of three nucleotides (4^3), which is sufficient to code 20 amino acids. On an mRNA molecule, a triplet of nucleotides is called a codon, nearly all codons code for a specific amino acid. All living organisms use the same genetic code; the genetic code is universal.

4. Outline the function of tRNA molecules.

tRNA molecules transfer amino acids to the ribosomes. There are at least 20 different tRNA molecules, each with a specific anticodon. The anticodon on the tRNA will only bind to a complementary codon on the mRNA. Complementary base-pairing ensures that amino acids are added in the correct sequence at the ribosome.

5. Describe the process of translation.

There are many different tRNA molecules in the cytoplasm carrying different amino acids. Ribosome attaches to mRNA at the start codon. tRNA molecules can be positioned over the mRNA in one of three sites in the ribosome. A tRNA with a complementary anticodon binds to the start codon on the mRNA. A second tRNA with an anticodon complementary to the next codon binds to mRNA. A peptide bond forms between the 2 amino acids. The ribosome moves along one codon. The first tRNA (now without an attached amino acid) floats away. A third tRNA (with an anticodon complementary to the third codon) now enters the ribosome and the amino acid chain grows. Ribosome continues until the stop codon. The ribosome, mRNA, and polypeptide chain are released.

7.1 DNA Structure and replication

1. Explain the process of DNA replication. [8m]

DNA replication is a semi-conservative process that occurs in the S phase of interphase. Helicase uncoils the DNA double helix into two strands, breaking the hydrogen bonds. One strand, the antisense strand, is used as the template strand. DNA primase adds a short length of RNA primer to the parent DNA. This allows DNA polymerase to be attached. DNA polymerase III adds nucleotides in the 5’ to 3’ direction. Adenine pairs with thymine while cytosine pairs with guanine by complementary base pairing. Deoxynucleoside triphosphate provides the energy required for this process. The synthesis of DNA is continuous on the leading strand but not on the lagging strand, causing the formation of Okazaki fragments. DNA polymerase I replace the RNA primer with DNA nucleotides. DNA ligase joins the Okazaki fragments, sealing the nicks and forming the continuous sugar-phosphate bond.

2. Explain the roles of specific enzymes in prokaryotic DNA replication. [8m]

- Helicase unwinds the DNA double helix, breaking hydrogen bonds between the DNA strands to create a replication fork.
- DNA gyrase supports unwinding of the DNA by relieving tension in the double helix
- DNA primase adds a short RNA primer, creating a short double-stranded region which allows DNA polymerase III to bind
- DNA polymerase III joins nucleotides in a 5' to 3' direction, synthesising the complementary strand
- DNA polymerase I removes the primer and replaces it with DNA nucleotides
- DNA ligase seals the nicks, linking Okazaki fragments and connecting the sugar-phosphate backbone

3. Outline the functions of coding and non-coding regions of DNA

- Coding regions of DNA code for proteins. They are transcribed and translated to produce proteins.
- Non-coding regions of DNA do not code for proteins but have several other important functions
    - Controlling gene expression: the promoter region of a gene is not transcribed but regulates transcription
    - Introns are transcribed but are removed by splicing before the mRNA leaves the nucleus to be translated. They are involved in mRNA processing.
    - Telomeres cap the ends of chromosomes, preventing them from shortening

4. What are nucleosomes and what is their role?

- Nucleosomes consist of DNA wrapped around histones. Each nucleosome has a core of eight histone proteins. The DNA-histone complex is called chromatin
- Histones within the nucleosome help DNA to be packaged inside the nucleus. Condensation of chromosomes is caused by nucleosomes associating together, which is supercoiling. Nucleosomes control the degree of supercoiling.

7.2 Transcription and gene expression

1. Outline the process of transcription leading to the formation of mRNA. [8m]

Transcription is the synthesis of RNA from a coding strand of DNA. The antisense strand acts as the template. RNA polymerase binds to the promoter region of DNA, separating the strands. The unwinding of the DNA helix exposes DNA bases for complementary base pairing with

RNA nucleotides. Adenine pairs with uracil and guanine pairs with cytosine. Nucleotides are added in the 5' to 3' direction, joined with covalent bonds between the sugar and phosphate. Hydrolysis of 2 phosphate molecules from nucleoside triphosphate provides the energy required for this reaction. When the terminator signal is reached, the RNA polymerase separates from DNA, and the DNA rewinds into a helix. In eukaryotes, introns are removed to form mature mRNA.

2. Explain the control of gene expression in eukaryotes. [8m]

Gene expression requires the production of specific mRNA through transcription. Some genes are only expressed at certain times and some genes are only expressed in certain cells. Hormones or chemical environments can affect gene expression, for example, auxin hormone in plants. Transcription factors or proteins may prevent or enhance the binding of RNA polymerase. Nucleosomes limit access of transcription factors to DNA, regulating gene expression. DNA methylation promotes the coiling of DNA by nucleosomes and stops transcription. Methylation of DNA is coordinated with chemical modification of histones which is an epigenetic factor. Introns may contain positive or negative gene regulators and gene expression can be regulated by post-transcriptional modification, splicing, or mRNA processing.

3. Outline the process that takes place in eukaryotes to modify the mRNA.

In eukaryotes, post-transcriptional modification occurs to regulate gene expression. The transcribed region of a gene contains protein-coding regions (exons) separated by non-coding regions (introns). After the mRNA has been synthesised by RNA polymerase, the introns are removed by RNA splicing. Splicing occurs in the nucleus and produces a mature mRNA molecule. The mature mRNA molecule leaves the nucleus to be translated in the cytoplasm. Prokaryotes do not have introns.

7.3 Translation

1. Explain the process of translation. [8m]

Translation involves initiation, elongation, and termination. mRNA binds with the small subunit of the ribosome, which slides along mRNA to the start codon. The anticodon of tRNA pairs with the start codon on mRNA by hydrogen bonding, following complementary base pairing. tRNA activating enzymes attach specific amino acids to tRNA. The first tRNA binds to the P site and the second tRNA binds to the A site. A

peptide bond forms between the amino acids on tRNA on the P and A sites. The ribosome moves along the mRNA to the next codon in a 5' to 3' direction. The tRNA with no amino acid is detached from the E site. The process continues until a stop codon is reached when release factors are secreted and the ribosome complex disassembles to stop polypeptide synthesis.

2. Outline the roles of the different binding sites for tRNA on ribosomes during translation. [4m]

A, P and E binding sites are on the large subunit of the ribosome. The large subunit binds with the start tRNA in the P site. The A binding site holds the tRNA with the next amino acid to be added. A peptide bond is formed between the amino acid in the A site and the polypeptide in the P site. The polypeptide is transferred to the tRNA in the A site. The P binding site holds the tRNA attached to the growing polypeptide. At the E binding site, the tRNA without an amino acid leaves the ribosome.

3. Describe the structure of a tRNA molecule.

tRNA has a stem-loop structure. The stem regions are double-stranded due to hydrogen bonding between complementary base pairs. There are three loops, with no base pairs. One of the loops is the anticodon loop and contains the three base anticodon sequence. There is an amino acid attachment site at the 3’ end of the tRNA molecule.

4. Describe the structure of a ribosome. [6m]

Ribosomes are comprised of protein and rRNA. It is organised into a globular shape with a large and small subunit. There are three tRNA binding sites (A, P, E) on the large subunit and a binding site for mRNA on the small subunit. rRNA catalyses the formation of peptide bonds between amino acids. In prokaryotes, ribosomes are 70S and in eukaryotes, ribosomes are 80S. They can exist either as free or bound to the rough endoplasmic reticulum in eukaryotes.

5. Distinguish between proteins synthesised on free ribosomes and those synthesised on ribosomes associated with the rough endoplasmic reticulum.

- Proteins synthesised on free ribosomes function within the cytoplasm
- Proteins synthesised by ribosomes associated with the rER are typically secreted by exocytosis (e.g. antibodies), become plasma membrane proteins (e.g. voltage-gated potassium ion channels) or function in membrane-bound organelles (e.g. digestive enzymes within lysosymes).

2.8 & 7.2 Cell Respiration

1. Distinguish between aerobic and anaerobic respiration. [5m]

Aerobic	Anaerobic
• Requires O_2 • In cytoplasm and mitochondria • O_2 reduced • High yield of ATP • High yield of NADH • FADH produced • End products CO_2 and H_2O • Involves electron transport chain and Krebs cycle	• Does not require O_2 • In cytoplasm • Pyruvate reduced • Low yield of ATP • Lower yield of NADH • FADH not produced • End products: ethanol & CO_2 (plants/yeast), lactic acid (humans) • Does not involve electron transport chain and Krebs cycle

2. Outline the role of electron carriers in cell respiration.

Electron carriers are molecules that can accept or donate electrons. In cell respiration, the electron carriers include NAD^+, FAD, and the components of the electron transport chain (ETC). Electron carriers exist in reduced or oxidised forms. In the metabolic pathways of cell respiration, oxidation of a substrate is coupled to the reduction of an electron carrier. The substrate loses 2 H atoms and is oxidised. Oxidised NAD accepts 2 electrons and 1 H^+ from the substrate, whereas oxidised FAD accepts 2 electrons and 1 H^+ from the substrate, whereas oxidised FAD accepts 2 electrons and 2 H^+ from the substrate. NAD and FAD are also hydrogen carriers. At the cristae, the reduced FAD and NAD are oxidised, donating their electrons to electron carriers in the ETC. the flow of electrons down the ETC involves a series of redox reactions.

3. Outline the main stages of anaerobic respiration.

- Glycolysis occurs in the cytoplasm. Each glucose molecule is converted to 2 pyruvates, without the use of O_2 and with the production of a small yield of ATP.
- The link reaction takes place in the mitochondrial matrix. Pyruvate is converted to acetyl-CoA, with the use of O_2. It links glycolysis to the Krebs cycle.
- The Krebs cycle occurs in the mitochondrial matrix. Acetyl-CoA combines with a 4C compound in a cycle of reactions, with the use of O_2.
- Oxidative phosphorylation involves the electron transport chain and chemiosmosis. It takes place in the cristae of the mitochondria. Energy is generated from the oxidation of glucose to produce ATP, in the presence of O_2.

4. Outline the process of glycolysis. [5m]

Glycolysis occurs in the cytoplasm. A 6C hexose is phosphorylated using ATP, making it unstable. Hexose bisphosphate is split into 2 molecules of triose phosphate. Triosephosphate is oxidised by the removal of hydrogen. Oxidation of substrate is coupled to the reduction of NAD^+. Some energy released is conserved in NADH, the reduced form of NAD^+. Pyruvate is produced at the end of glycolysis, with a net gain of 2 ATP.

5. Describe the link reaction.

Pyruvate is converted to a 2 carbon acetyl group by oxidative decarboxylation. Pyruvate is oxidised as hydrogen is lost coupled with the reduction of NAD^+. Decarboxylation occurs as CO_2 is lost as the waste product of respiration. Finally, the acetyl group combines with coenzyme A to form acetyl CoA.

6. Describe the Krebs cycle.

The Krebs cycle only occurs in aerobic conditions, in the presence of oxygen, taking place in the mitochondria. Acetyl CoA from the link reaction releases an acetyl group. NADH + H^+ and CO_2 are produced with each decarboxylation, with the release of energy. An acetyl group

is joined with a 4C molecule to form a 6C molecule. Decarboxylation changes the 6C to a 5C, which is then changed to a 4C molecule. The 4C molecule is then converted to the original 4C molecule, releasing 1 molecule of ATP. NADH, $FADH_2$, and CO_2 are end products of the reaction.

7. What is oxidative phosphorylation?

Most of the energy released from the stepwise oxidation of glucose is conserved. In the reduced hydrogen carriers, NADH and $FADH_2$. NADH and $FADH_2$ move to the cristae of the mitochondria, where oxidative phosphorylation occurs. Energy originally released from the oxidation of glucose is used to produce ATP from ADP and P_i. Oxidative phosphorylation involves the ETC, resulting in the creation of a proton gradient, and chemiosmosis, the production of ATP from energy held in the proton gradient.

8. Describe the role of the electron transport chain in oxidative phosphorylation.

NAD and FAD are electron carriers that become reduced when they gain 2 electrons to form NADH and $FADH_2$ respectively. NADH and $FADH_2$ donate 2 electrons each to an electron carrier in the ETC. The ETC is in the cristae of the mitochondria. As electrons flow from carrier to carrier in a series of redox reactions, energy is released. This energy is used by some electron carriers to pump protons from the matrix to the intermembrane space against a concentration gradient. Protons accumulate in the intermembrane space and a proton gradient is generated. Oxygen is the final electron acceptor.

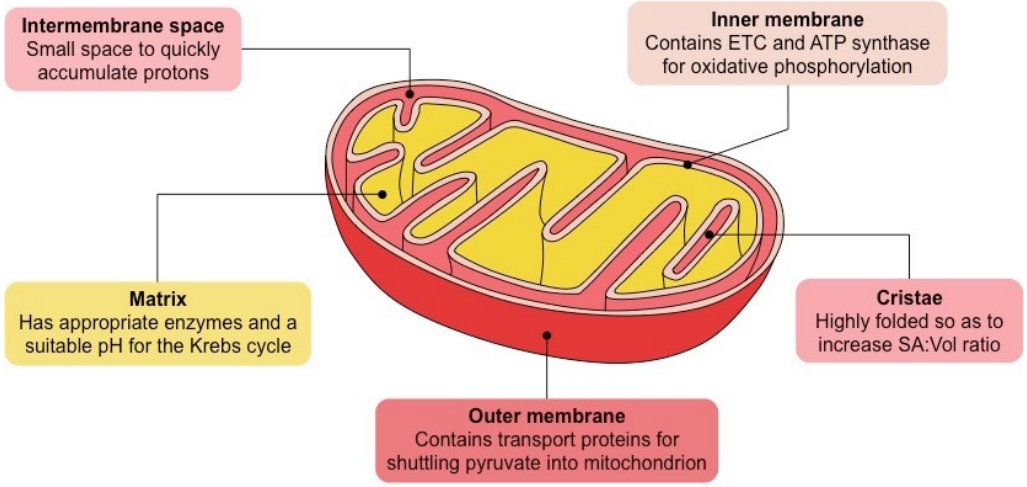
9. Describe the process of chemiosmosis.

The transport of electrons by the ETC generates a proton gradient between the intermembrane space and matrix. The energy held within the proton gradient is used to produce ATP, in a process called chemiosmosis. Chemiosmosis involves the enzyme ATP synthase which is embedded in the inner mitochondrial membrane. Energy is released as protons pass through the ATP synthase, from the intermembrane space into the matrix, down the proton gradient, via facilitated diffusion. ATP synthase converts ADP to ATP.

10. Describe the role of oxygen in aerobic cell respiration. [5m]

Oxygen acts as the final electron acceptor of the ETC. Oxygen also accepts electrons and is reduced. Reduced oxygen binds with the free protons to form water. The joining of protons and oxygen removes protons from the matrix, helping to maintain the proton gradient for chemiosmosis. Oxygen also helps to avoid the buildup of lactic acid by anaerobic respiration. It allows NAD^+ and FAD to be regenerated, allowing more electrons to be delivered to the ETC.

11. Draw and annotate a labelled diagram of a mitochondrion.

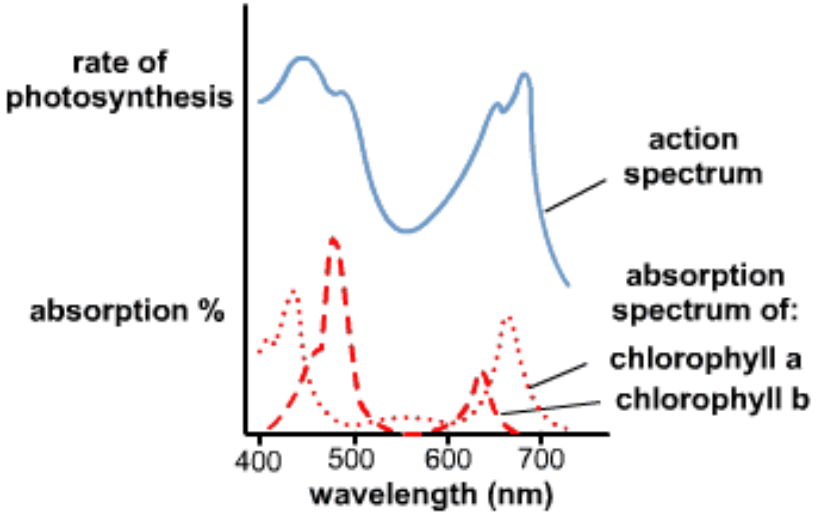


2.7 & 8.3 Photosynthesis

1. Draw and define the terms (i) absorption spectrum and (ii) action spectrum.

- An absorption spectrum is a graph that shows the amount of light that chlorophyll molecules absorb at different wavelengths of the visible spectrum. Chlorophyll pigments mainly absorb blue and red light and reflect green light.
- An action spectrum is a graph that shows the rate of photosynthesis at different wavelengths of the visible spectrum. The highest

rates of photosynthesis are when exposed to blue and red light (slightly higher in blue light).

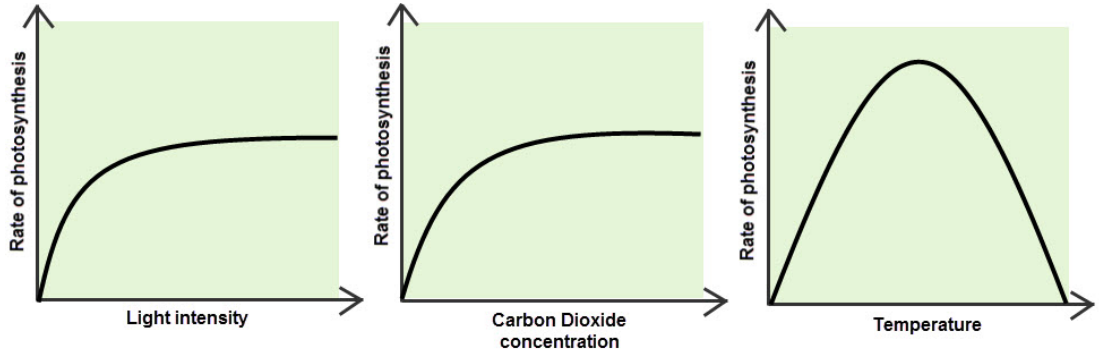


2. Outline the reactions of photosynthesis.

- The reactions of photosynthesis take place in the light-dependent and light-independent stages of photosynthesis.
- In the light-dependent reactions, light energy is absorbed by chlorophyll and used to split water molecules in a process known as photolysis. To produce ATP, hydrogen, electrons and oxygen are required. Oxygen is the waste product of photosynthesis. ATP, hydrogen and electrons are required for the second stage of photosynthesis.
- In the light-independent stage of photosynthesis, rubisco catalyses the fixation of carbon dioxide. The hydrogen and electrons react with CO_2 to produce carbohydrate molecules. Energy is needed to enable the reaction and is supplied by ATP. the carbohydrate produced can form glucose and other carbon compounds.

3. Outline the effect of (i) temperature, (ii) CO_2 concentration and (iii) light intensity on the rate of photosynthesis.

- As temperature increases, the photosynthetic rate increases. At optimum temperature, the maximum rate of photosynthesis is reached. At high temperatures, photosynthesis slows as enzymes involved in the reactions of photosynthesis are denatured. At high and low temperatures, the temperature is a limiting factor of photosynthesis. At optimum temperature, another factor will be limiting the rate of reaction.
- As CO_2 concentration increases, the rate of photosynthesis increases as there are more frequent effective collisions between CO_2 and rubisco. The rate of photosynthesis plateaus when a maximum rate of carbon fixation is reached, thus increasing CO_2 further has no effect and another factor becomes limiting.
- As light intensity increases, the photosynthetic rate increases. Light provides the energy to drive photosynthesis. At high light intensity, photosynthesis reaches a maximum rate and plateaus. Increasing the light intensity further will have no effect on the rate as all the chlorophyll molecules are saturated with light. Thus, another factor becomes limiting.



4. Outline how the structure of a chloroplast is linked to its function.

- Chloroplast envelope: creates a compartment within the cell specialised for the reactions and processes of photosynthesis
- Thylakoid membrane: contains photosystems, electron carriers and ATP synthase enzymes for the light-dependent reactions
- Thylakoid: flat, fluid-filled sacs called thylakoids. Small volume within thylakoid so that a high concentration of protons is rapidly achieved for chemiosmosis
- Grana: stacks of thylakoids provide a large surface area for the absorption of light and light-dependent reactions
- Stroma: contains enzymes for the Calvin cycle. 70S ribosomes and a loop of naked DNA are also present.
- Starch grain: an insoluble store of glucose produced by photosynthesis.

5. Describe the absorption of light by photosystems.

Chlorophyll molecules and other accessory pigments are organised into photosystems, photosystems are located in the thylakoid membrane and contain pigment molecules arranged to harvest light energy and channel it to the reaction center. Two types of photosystems exist, photosystem 1 (PS I) and photosystem 2 (PS II). Photosystems contain pigment molecules arranged to harvest light energy and channel it to the reaction center. When a chlorophyll molecule absorbs light, the energy from light excites an electron. The energy is transferred via pigment molecules to the reaction center. The reaction center contains a special pair of chlorophyll molecules. Electrons within the reaction center chlorophylls are excited. The reaction center chlorophylls can donate excited electrons, 2 at a time, to an electron acceptor which is called photoactivation.

6. Explain the light-dependent reactions of photosynthesis. [8m]

The light-dependent reactions occur on the thylakoid membranes. Chlorophyll in PS II absorbs light which excites electrons to a higher energy level. The electrons pass from carrier to carrier along the electron transport chain. Energy released from electrons is used to pump protons across the thylakoid membrane into the thylakoid space. ATP is generated by chemiosmosis, as protons pass through ATP synthase, via facilitated diffusion. Electrons from PS II pass to PS I, where photoactivation excites electrons to a higher energy level. Electrons from PS I are used to reduce NADP to NADPH. NADPH is passed to the Calvin's cycle to be used in the light-independent reactions to fix carbon. Oxygen from photolysis of water is a waste product and excreted.

7. Explain chemiosmosis as it occurs in photophosphorylation. [8m]

Photophosphorylation is the production of ATP. Some of the light is absorbed by chlorophyll molecules in PS II, which excites electrons to a higher energy level. Light energy is used to split water molecules by photolysis. The electrons are passed from carrier to carrier in the electron transport chain, which occurs in the thylakoid membrane. Energy released from electrons is used to pump protons into the thylakoid space, in which a high concentration of protons builds up. The small thylakoid space helps to create a steep proton gradient. The movement of H^+ by facilitated diffusion through ATP synthase, embedded in the thylakoid membrane, generates ATP. Chemiosmosis is the coupling of electron transport to ATP synthesis. In non-cyclic photophosphorylation, water is not required to replenish the electron supply

as the de-energised electron returns to PS II, restoring its electron supply.

8. Describe how autotrophs absorb light energy. [3m]

Light is absorbed by photosynthetic pigment chlorophyll. Photosystems are light-harvesting complexes containing chlorophyll. They are located in thylakoid membranes. Light energy is used to excite electrons to higher energy level.

9. Explain how water is used in photosynthesis. [3m]

- Water is split during photolysis which produces electrons. The electrons replace those lost by PS II and allow electrons to continue to pass along the ETC.
- Splitting water also provides protons inside the thylakoid to maintain a high proton gradient for chemiosmosis to occur.

10. Explain the light-independent reactions of photosynthesis. [8m]

The light-independent reactions of photosynthesis occurs in the stroma of the chloroplast, in a cycle known as the Calvin cycle. It requires ATP and NADPH provided by the light-dependent reactions. Carbon dioxide is fixed to ribulose bisphosphate (RuBP) by enzyme rubisco. This forms an unstable 6C compound that splits into 2 molecules of glycerate-3-phosphate (G3P). G3P is reduced to triose phosphate using NADPH which provides hydrogen. Some of the triose phosphates is converted to hexose sugars while most of the triose phosphate is converted to hexose sugars while most of the triose phosphate is used for regeneration of RuBP. ATP supplies the energy required for this reaction.

11. Describe the lollipop experiment and what was discovered about photosynthesis. [8m]

Calvin used algae suspended in a solution, placed inside a lollipop-shaped vessel that was thin and round to ensure that all the algae had equal light. The algae were given plenty of light and CO_2. at the start of the experiment, a short burst of radioactive carbon ^{14}C, was supplied. At regular intervals, samples of the algae were taken and added to hot methanol which kills the algae, stopping the

light-independent reactions. The samples were separated by two-way paper chromatography and identified by autoradiography. This showed that RuBP was phosphorylated. After 5 seconds, immediately more G3P is present in abundance, indicating that it is the first stable product. The next compound to be detected containing ^{14}C was triose phosphate. This showed that a wide range of carbon compounds was quickly made in sequence and showed that a cycle of reactions was used to regenerate RuBP.

3.1 Genes

1. Define the following terms: (i) genome, (ii) gene, (iii) gene locus, (iv) allele

- A genome is the complete set of genes or genetic material present in a cell or organism
- A gene is an inherited segment of DNA that controls a specific characteristic
- A gene locus is the specific location of a gene on a chromosome
- An allele is an alternative form of a gene, differing from other alleles by one or a few bases

2. Outline the outcomes of the human genome project (HGP). [4m]

The HGP sequenced the entire human genome and identified all human genes. This helped scientists find evidence for evolutionary relationships of humans, discover the functions of proteins, single nucleotide polymorphisms or base substitutions and develop new drugs or gene therapies based on base sequences. The HGP also promoted international collaboration and cooperation between scientists.

3. What is a gene mutation?

A gene mutation is a random change in the DNA sequence. The mutation rate can be increased by exposure to mutagens, such as carcinogens. Mutations lead to the creation of new alleles, which leads to genetic variation.

4. Explain the causes of sickle-cell anaemia. [8m]

Sickle cell anaemia is caused by a single gene mutation called base substitution. This changes the code on the DNA which leads to a

change in transcription. The DNA triplet on the sense strand changes from GAG to GTG while the mRNA codon changes from GAG to GUG. This in turn leads to a change in translation. The tRNA adds the amino acid valine instead of glutamic acid to the polypeptide. As a result, the individual produces abnormal haemoglobin which causes red blood cells to be sickle-shaped, lowering the ability of red blood cells to transport oxygen. The sickle-cell allele is codominant. The homozygous form, HbS HbS is lethal and have sickle-cell anaemia. The heterozygous form, HbS HbA, is a carrier for the sickle-cell trait is more resistant to malaria.

3.2 Chromosomes

1. Distinguish between prokaryotic and eukaryotic chromosomes.

Prokaryotes	Eukaryotes
Naked DNA	DNA associated with histone proteins
Circular	Linear
One chromosome	At least two chromosomes
Free in the cytoplasm	Contained in nucleus

2. Outline the structural and genetic characteristics of eukaryotic chromosomes. [4m]

Eukaryotic chromosomes consist of linear DNA, which is associated with histone proteins. Centromeres join sister chromatids and telomeres are at the end of the chromatids. Eukaryotic chromosomes carry a specific sequence of genes which occupy a specific locus on the chromosome. Homologous chromosomes have the same sequence of genes and they exist in pairs. Eukaryotic chromosomes also have non-coding sequences, e.g. introns. They supercoil during mitosis.

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Define the terms chromatid, sister chromatids and chromosomes, diploid
and haploid, genotype, phenotype, dominant,recesisve, co-dominant,
homozygous dominant, homozygous recessive
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3. Compare chromosome numbers in cells with a diploid or haploid nucleus.

- Cells with a diploid nucleus are somatic or body cells. In humans, a diploid nucleus contains 46 chromosomes, with 23 pairs of different chromosomes, which are homologous. This means that the chromosomes in each pair contain the same genes in the same order but may have different alleles of each gene.
- Cells with a haploid nucleus are sex cells, or gametes, such as a sperm cell. A haploid nucleus only contains one chromosome of each homologous pair, thus only have 23 chromosomes.

4. Define karyotyping and explain its use in human genetics. [8m]

- Karyotype is the number and type of chromosomes present in a cell. Cells are collected from the chorionic villus by amniocentesis. The cells are stimulated to divide and reach metaphase, then an image of the chromosomes, known as a karyogram, is taken. The karyogram shows chromosomes arranged in homologous pairs according to their size.
- Karyograms are used to determine sex. The sex chromosomes for males are XY and females are XX. karyograms also identify chromosome abnormality or mutations and can be used to diagnose conditions. For example, an extra chromosome 21 indicates Down's syndrome.

3.3 & 10.1 Meiosis

1. Define meiosis. State its importance in the production of gametes to allow a sexual life cycle.

- Meiosis is a reduction division of the nucleus. A diploid nucleus decides to form 4 haploid nuclei
- Organisms with a sexual life cycle produce gametes. During fertilisation, gametes fuse to form a zygote. The diploid number of chromosomes is restored. Meiosis enables a constant chromosome number to be maintained through the generations.

2. Summarise the process of meiosis.

- Meiosis has 2 divisions, meiosis I and meiosis II. DNA replication occurs before meiosis. Meiosis I separates the homologous pairs of chromosomes, producing haploid cells. Meiosis II separates the sister chromatids. The chromosome number is halved by

meiosis, due to the separation of homologous chromosomes in meiosis I.

3. Outline the events that occur during meiosis I.

- During prophase I, the nuclear membrane begins to break down. The homologous chromosomes pair up to form bivalents. The chromosomes condense and crossing over occurs.
- During metaphasse I, pairs of homologous chromosomes line up along the equator. Spindle microtubules from the two poles attach to different chromosomes in each pair.
- During anaphase I, the homologous chromosomes are pulled to opposite poles, halving the chromosome number.
- During telophase I, the chromosomes uncoil, becoming less condensed, and the nuclear membrane reforms.
- Cytokinesis divides the cell, halving the chromosome number to produce haploid cells. Each chromosome still consists of sister chromatids.

4. Outline how meiosis promotes genetic variation.

- Crossing over occurs during prophase I of meiosis after homologous chromosomes pair up. Crossing over is the exchange of genetic material between non-sister chromatids of a homologous pair of chromosomes. This produces chromatids with a new combination of alleles.
- Random orientation of pairs of homologous chromosomes occurs in metaphase I. There are 2 possible ways each homologous chromosomes occur in metaphase I. There are 2 possible ways each homologous chromosomes occur in metaphase I. there are 2 possible ways each homologous pair can be orientated at the cell equator and it is random. In humans, there are 2^{23} ways the chromosomes can be arranged. This leads to different combinations of alleles in gametes.
- Random fertilisation promotes genetic variation. Any sperm from the father can fuse with any egg from the mother and each gamete produced is unique. Hence, a unique combination of alleles is achieved by fertilisation.

5. What is crossing over and how does it create genetic variation?

During prophase I, homologous chromosomes pair up to form bivalents. Each chromosome comprises two sister chromatids, joined at the

centromere. Sister chromatids are formed by DNA replication, in the S phase of interphase before meiosis begins. Crossing over is the exchange of genetic material between non-sister chromatids of a homologous pair of chromosomes. The formation of recombinant chromatids by crossing over results in the exchange of alleles. Crossing over occurs at random locations and can occur multiple times in each bivalent. Thus, the chromosomes in the gametes produced will have new combinations of alleles, creating genetic variation.

6. Outline the formation of chiasmata during crossing over. [5m]

Crossing over occurs during prophase I of meiosis. Homologous chromosomes are paired up to form bivalents in a process called synapsis. Chromatids break at the same point in adjacent non-sister chromatids. Non-sister chromatids join each other at the breakpoints. This results in a section of the non-sister chromatids being exchanged, producing recombinant chromatids. Chiasma is formed at the position where crossing over occurs. They become visible when homologous chromosomes separate. Non-sister chromatids remain joined at these points and appear as X-shaped structures. Chiasma is lost when the homologous chromosomes are separated during anaphase I.

7. Outline how random orientation of homologous chromosomes in meiosis I result in the independent assortment of genes.

The law of independent assortment states that pairs of alleles from 2 different genes separate independently of each other when gametes are formed. This is a consequence of random orientation of homologous pairs of chromosomes during metaphase I. there are 2 possible ways each homologous pair can be orientated at the cell equator. It is random for each pair and each pair is independent from the other pairs. Homologous pairs are then separated in the following stages of meiosis I. Sister chromatids are separated in meiosis II. In the gametes produced, each possible combination of allele has an equal chance of being formed.

8. Outline how non-disjunction can lead to chromosome abnormalities, including Down's syndrome. [8m]

Down's syndrome is caused by non-disjunction during meiosis, which leads to one extra or missing chromosome in gametes. This can happen during anaphase I, when homologous chromosomes do not separate due to incorrect spindle attachment, or during anaphase II when sister chromatids do not separate due to centromeres not dividing. Thus, some gametes will have an extra chromosome. Fertilisation involving a gamete with an extra chromosome forms a zygote with 3 copies of one chromosome, known as trisomy. Down's syndrome is

due to an extra chromosome 21, called trisomy 21. The probability of Down's syndrome increases with the age of the parents.

9. Outline the two methods which enable cells to be collected for prenatal diagnosis of chromosomal abnormalities?

- In chorionic villus sampling (CVS), cells are removed from the chorionic villus, a part of the placenta, with a tube via the cervix, or with a needle through the abdomen wall.
- In amniocentesis, a sample of amniotic fluid is removed from the amniotic sac, using a hypodermic needle, inserted through the abdomen wall. Amniotic fluid containing fetal cells is drawn out into a syringe. The risk of miscarriage is higher than in CVS.
- After cells are collected, they are stimulated to divide so metaphase chromosomes can be obtained for karyotyping.

3.4 & 10.2 Inheritance

1. Define the terms: (i) genotype, (ii) phenotype, (iii) dominant allele, (iv) recessive allele, (v) homozygous, (vi) heterozygous

- A genotype is the combination of all the alleles in an organism
- A phenotype is the observed characteristics of an organism, determined by genotype
- A dominant allele masks the presence of a recessive allele. The observed phenotype is the same when present in a homozygous or heterozygous state.
- A recessive allele is masked by the presence of a dominant allele. The phenotype of a recessive allele is only observed when it is in the homozygous state.
- Homologous refers to both alleles of the genes which are the same
- Heterozygous refers to both alleles of the genes which are different

2. Describe codominance and multiple alleles using inheritance of ABO blood groups as an example of them. [6m]

In multiple alleles, there are more than 2 alleles of a gene. Codominance refers to both alleles affecting the phenotype in the heterozygous

form. The alleles controlling blood groups are I^A, I^B and i. The I^A and I^B alleles are codominant; when both are present this gives rise to AB blood group. The i alleles is recessive to both I^A and I^B and only give rise to blood group O when it is present in homozygous form. Type A and B can have heterozygous genotypes, such as I^Bi and I^Ai, or homozygous genotypes such as I^AI^A and I^BI^B.

3. Explain how males inherit hemophilia and how females can become carriers for the condition. [8m]

Hemophilia is due to a recessive allele and is sex-linked. It is represented by X^h as the allele is on the X chromosome. Males have sex chromosomes XY while females have XX. Y chromosomes do not have the allele, so males have a 50% chance of inheriting the X^h allele from their mother who is a carrier. As males only have one copy of the X gene, they cannot be carriers and a hemophiliac male would have X^hY gene. The female carrier is heterozygous for the gene, X^HX^h, but does not have hemophilia because the dominant allele masks the recessive X^h allele. Hemophiliac males will have daughters who are carriers and the hemophiliac allele could have been inherited from either parent.

4. Describe the segregation of unlinked genes.

The law of independent assortment states that pairs of alleles from 2 different genes separate independently of each other during the formation of gametes. This is due to the random orientation of chromosomes during metaphase I. Independent assortment will only occur if the genes are unlinked, which means that genes are located on different chromosomes.

5. Distinguish continuous and discrete variation.

Discrete	Continuous
Characteristic in categories (no intermediate phenotype)	Continuous range (usually a normal distribution)
Determined by a single gene	Involves genes and the environment

E.g. blood group, eye colour	E.g. skin colour, human height

6. Describe how human skin is determined genetically. [5m]

Skin colour is an example of a polygenic inheritance which means more than 2 genes contribute to a person's skin colour. Skin colour is due to the amount of melanin in the skin. The combination of alleles determines the phenotype which produces a continuous variation. The environment also affects the gene expression of the skin colour, e.g. sunlight stimulations the production of melanin

3.5 Genetic modification and biotechnology

1. Outline the technique of gel electrophoresis.

Gel electrophoresis is used to separate DNA fragments or proteins according to their molecular size. The gel has a porous structure that allows DNA fragments or proteins to pass through. An electric current is used to move the molecules through the gel. As DNA is negatively charged, it will be attracted to the positive electrode. Proteins are treated to become negatively charged. Larger molecules move more slowly through the pores of the gel than the smaller ones. Hence, smaller molecules will travel further through the gel than larger molecules in a small amount of time.

2. Outline the method of polymerase chain reaction (PCR).

- PCR is a method used to amplify very small amounts of DNA to obtain large amounts of DNA for analysis. DNA can be collected from very small samples of semen, blood, hair or saliva. A doubling of DNA occurs every cycle, produces over a billion DNA molecules in 30 cycles. There are 3 steps in each cycle:
- Step 1 (Denaturation): DNA strands are separated by heating to 94^{o}C
- Step 2 (Annealing): The temperature is lowered to 45^{o}C to allow the primers to bind to the 3' end of both strands of DNA
- Step 3 (Elongation): The temperature is raised to 72^{o}C to provide optimum temperature for Taq DNA polymerase to replicate both strands, producing two double-stranded copies of the DNA, extending from the primers.

3. Explain the method of DNA profiling and its aims.

- A DNA sample is obtained from hair, blood or semen. The sample containing many repeated units of short DNA sequences, or short tandem repeats (STRs), is amplified by PCR. the DNA is then cut into fragments using restriction endonucleases. Gel electrophoresis is used to separate the DNA fragments by size. The pattern of bands revealed by gel electrophoresis will be unique to each individual.
- The main uses of DNA profiling include forensics, e.g. placing a suspect to a crime scene, and paternity testing use, e.g to investigate a child's biological father.

4. Outline the process of gene transfer to create genetically modified bacteria.

- A genetically modified organism (GMO) contains a gene from a different species
- Step 1: Isolate the gene of interest (e.g. the insulin gene). Cut human DNA with a restriction endonuclease.
- Step 2: Cut a plasmid with the same restriction endonuclease used to cut the human DNA. This produces sticky ends.
- Step 3: Mix cut plasmids and the insulin gene with DNA ligase to join the DNA. The plasmids are now called recombinant DNA molecule as it contains DNA from 2 species
- Step 4: The recombinant plasmids are inserted into bacteria host cells using a bacterium
- Step 5: The genetically modified bacteria are grown in large fermenters which provide optimum conditions for insulin to be extracted

5. Outline the role of the following in the process of gene transfer: (i) vector, (ii) restriction endonuclease, (iii) DNA ligase, (iv) reverse transcriptase, (v) host organism

- Vector: used to transfer genes between species. (e.g. plasmids)
- Restriction endonuclease: used to cut DNA at specific recognition sequences
- DNA ligase: when sticky ends join back together due to complementary base pairing, DNA ligase is needed to join the sugar-phosphate backbone back together
- Reverse transcriptase: to synthesise a DNA copy from an mRNA molecule
- Host organism: the organism that the vector is transferred into

6. Assess the benefits and risks of genetically modified crops using Bt maize as an example.

Benefits	Risks
● Increased crop yields / more food produced ● Increased pest resistance / reduced use of chemical insecticides ● Improves crops to be more nutritious / increased vitamin content	● Risk to non-target insects e.g. Monarch butterflies ● Insects may become resistant to Bt toxin ● Transfer to Bt gene to wild relatives of corn by cross-pollination, affecting insects

7. What is a clone and how are they produced?

- A clone is an organism derived from a single parent cell and is genetically identical to the parent cell
- Cloning can occur naturally, such as in asexual reproduction. Plants can form tubers, bulbs, or runners. Animals, such as hydra, bud off new individuals
- Cloning can also occur artificially. In plants, cuttings are taken from the stem and uprooted. In animals, embryos can be isolated and broken up. Each smaller group of cells will produce an individual. Another method is somatic-cell nuclear transfer, the manipulation of reproductive cells.

8. Outline the process of somatic cell nuclear transfer (SCMT).

- SCMT allows adult animals to be cloned from a differentiated body cell. This method was used to clone Dolly the sheep.
- An udder cell was removed from an adult donor sheep
- A second sheep provides an unfertilised egg. The nucleus is removed from the egg.
- The udder cell and the egg without the nucleus are fused. Electrical pulses are given to facilitate the fusion.
- The fused cell is grown in culture until it reaches the 16 cell stage. It is then implanted into a third sheep, the surrogate mother.
- The surrogate mother gives birth to the cloned lamb, which is genetically identical to the donor sheep.

9. Discuss the ethical issues of therapeutic cloning in humans. [8m]

- Therapeutic cloning is the creation of an embryo to supply embryonic stem cells for medical use. It involves the transfer of a nucleus from a somatic cell into an enucleated egg, stimulated by an electric shock to begin cell division.

Advantages	Disadvantages
• Stem cells from embryos have greater flexibility • Pluripotent cells can give rise to all cells in the body, so a new organ could be grown • There is no danger of organ rejection because the DNA matches exactly • Eliminate organ and tissue shortages • No need for immunosuppressive drugs	• Manipulation or destruction of human embryos is not ethically acceptable • The process of extracting stem cells involves killing the embryo

4.1 Species, Communities and Ecosystems

1. Define the following terms: (i) species, (ii) population, (iii) community, (iv) ecosystem

- Species: A group of organisms that can interbreed to produce fertile offspring
- Population: A group of organisms of the same species living in the same area at the same time
- Community: Populations of different species living and interacting with each other in an area
- Ecosystem: A community interacting with its abiotic environment

2. Define the following terms: (i) autotroph, (ii) heterotroph, (iii) saprotroph, (iv) consumer, (v) detritivore

- Autotroph: An organism that synthesises organic carbon compounds from inorganic nutrients, using an external energy source, such as the Sun
- Heterotroph: An organism that obtains organic carbon compounds from other organisms
- Saprotroph: A heterotroph that lives in or on non-living organic matter, secreting digestive enzymes and absorbing digested

molecules. They digest nutrients externally. (e.g. bacteria, fungi)
- Consumer: A heterotroph that ingests living or recently killed organisms
- Detritivore: A heterotroph that ingests non-living organic nutrients (detritus). They digest nutrients internally.

3. Outline what an ecosystem requires to be sustainable.

An ecosystem requires an external energy source, such as the Sun. Autotrophs are required to synthesise organic carbon compounds from inorganic nutrients. Saprotrophs are required for nutrient cycling. Nutrients in an ecosystem are finite and limited. Saprotrophs release inorganic nutrients back into the abiotic environment to supply autotrophs. Otherwise, the nutrients would be locked into dead organisms and unavailable. Populations are limited by competition for resources and predator-prey relationships.

4. Distinguish between the transfers of energy and inorganic nutrients in ecosystems. [2m]

Energy is lost between trophic levels and not recycled, while nutrients can be reused.

5. Outline how producers use phosphates and nitrates from the soil, in the synthesis of organic molecules. [2m]

Producers use energy from the Sun to synthesise carbon compounds. Phosphates are used to make phospholipids and nucleic acids while nitrates are used to make amino acids and proteins. These molecules are transported from roots to leaves in the xylem.

4.2 Energy Flow

1. Define the term 'trophic level'.

Trophic level is the feeding position of an organism in a food chain.

2. Outline energy flow through a food chain. [4m]

Energy from the Sun is converted to chemical energy in autotrophs via photosynthesis. Chemical energy flows through the food chain via consumers feeding on the previous trophic level. Energy from respiration is used by living organisms and converted to heat energy, which is lost from food chains. Energy is also lost through excretion, uneaten body parts, egestion, or feces. Energy transfers only 10% between trophic levels, thus limiting the length of food chains. Energy flow through the food chain is linear.

3. Outline how energy and biomass are lost at each trophic level.

- Energy transfer between trophic levels is approximately 10%. Some material is not consumed, such as bones. Of the organic carbon compounds eaten, only a small fraction becomes part of the organism; most of the food is used as an energy source. Energy is lost through cell respiration as heat, through feces or excreted in urine.
- Biomass is lost when waste products of metabolism are excreted. Carbon dioxide and water are waste products of cell respiration. Urea is lost in urine and is produced when excess amino acids are broken down.

4. Distinguish the way energy and nutrients move in an ecosystem.

- Energy flows through an ecosystem. Energy enters most ecosystems in the form of sunlight, which is an unlimited resource. Energy movies through the ecosystem in organic compounds and is lost in the form of heat due to cell respiration.
- Nutrients are recycled, as they are finite and limited. Saprotrophs have a key role in recycling inorganic nutrients.

5. Describe the reasons for the shape of a pyramid of energy. [3m]

A pyramid of energy has a stepped shape with the largest bottom step being producers, which converts light energy to chemical energy in carbon compounds by photosynthesis. Energy is transferred to primary and secondary consumers via feeding on organic molecules. Energy released by respiration is used in living organisms and converted to heat, which is lost from ecosystems. Energy is also [redacted] Approximately 10% of energy in trophic levels is converted into new material for the next trophic level.

6. Describe what is meant by a food chain and food web. [6m]

- A food chain shows the transfer of nutrients or energy in an ecosystem, from one trophic level to another. It starts with a producer, followed by at least 2 levels of consumers. Food chains typically consist of up to 4 trophic levels as there is insufficient energy to support the upper stages
- A food web is the branched interaction of multiple food chains within an ecosystem. It can have multiple producers, transferring nutrients and energy to consumers from different food chains. The same consumer could be at different trophic levels in a food web.

4.3 Carbon Cycling

1. Outline the production of methane and how it is converted into carbon dioxide.

Methane is produced from organic carbon compounds in anaerobic conditions. Anaerobic conditions can occur in waterlogged soil, such as swamps. Methanogenic archaeans partially break down organic carbon compounds to form methane. Methane can accumulate in the ground or diffuse into the atmosphere. Methane does not build up to high levels in the atmosphere as it is oxidised to form carbon dioxide and water.

2. Outline the formation of the following 2 fossil fuels: (i) Coal, (ii) Oil and gas

- Saprotrophic cannot break down organic compounds fully in acidic and anaerobic conditions. These conditions are found in bogs and swamps. Acidic conditions denature enzymes involved in cell respiration. Partially decomposed plant remains build up over time and form peat. Over geological eras, peat is converted to coal.
- Silt and organic remains, from algae, plants and animals, are deposited. Due to anaerobic conditions, only partial decomposition occurs. Over geological eras, silt is converted to shale, with organic compounds being converted to oil or gas that is trapped in porous rock.

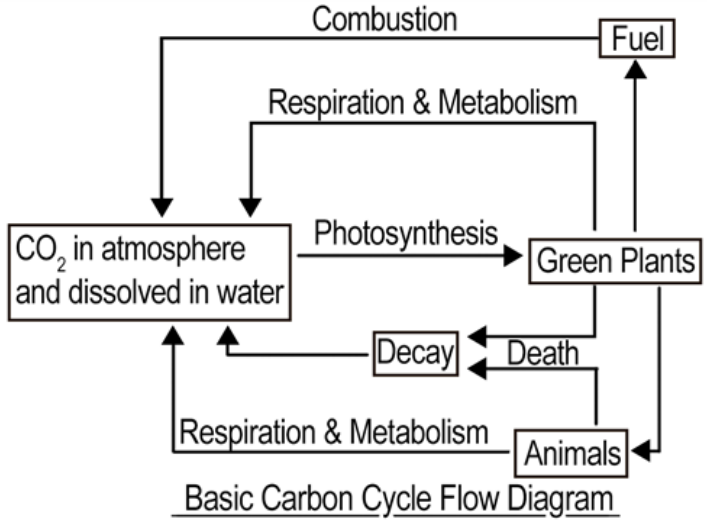
3. Outline the formation of limestone.

The shells of marine molluscs are made of calcium carbonate. The hard outer skeletons of corals are also made of calcium carbonate. Corals gradually build reefs over long periods of time. When marine molluscs and corals die, debris from their shells and skeletons accumulate on the seafloor sediment. Over geological eras, the sediment forms limestone. The shells of marine molluscs and coral skeletons may become fossilised in limestone.

4. How is carbon locked away in biomass, fossil fuels and limestone be released as carbon dioxide into the atmosphere?

- Carbon locked away in biomass and fossil fuels can be released by combustion. Complete combustion of organic matter will produce carbon dioxide and water. Forest fires and the combustion of fossil fuels release carbon dioxide into the atmosphere.
- Carbon can be released from limestone by the action of acid. Rainwater contains carbonic acid and results in the breakdown of calcium carbonate to release carbon dioxide into the atmosphere.

5. Draw a labelled diagram of the carbon cycle. [6m]



Basic Carbon Cycle Flow Diagram

6. Outline the roles of living organisms in the carbon cycle. [8m]

Producers fix carbon dioxide in photosynthesis to produce sugars and carbon compounds. The carbon compounds in producers are eaten by primary consumers. Primary consumers are eaten by secondary consumers, passing energy along the food chain. Carbon compounds and organic molecules are digested and absorbed by consumers. Carbon dioxide is released by cell respiration in plants and animals. Plants and animals die and are decomposed by saprotrophic bacteria and fungi. Carbon dioxide is released by cell respiration in decomposers. Enzymes are released to digest the carbon compounds in organic matter. Forest fires and the combustion of fossil fuels releases carbon dioxide into the atmosphere.

4.4 Climate Change

1. Outline the greenhouse effect.

Short wave radiation from the Sun reaches the Earth. Some are reflected by the Earth's atmosphere, but most of it is absorbed by the Earth's surface. The Earth's surface warms up and emits long-wave infrared radiation. Some of it escapes into space, but most are absorbed by greenhouse gases in the atmosphere. The greenhouse gases scatter the longer-wave radiation. This traps heat in the atmosphere, known as the greenhouse effect.

2. Outline how greenhouse gases interact with radiation and contribute to global warming. [4m]

Greenhouse gases include carbon dioxide, methane, nitrogen oxide and water vapour. Short-wave radiation from the Sun passes through the atmosphere to reach the Earth's surface. Greenhouse gases absorb and trap the radiation, converting it to heat. The Earth's surface warming up emits longer-wave radiation. Greenhouse gases in the atmosphere trap the infra-red radiation and re-emits it back to the surface of the earth, which is the greenhouse effect that contributes to global warming.

3. Outline the causes and consequences of the enhanced greenhouse effect. [5m]

Increase of greenhouse gases in the atmosphere leads to an enhanced greenhouse effect. Burning of fossil fuels, coal, oil or gas releases carbon dioxide. Deforestation reduces carbon dioxide uptake by plants. Methane emitted from cattle and livestock increases carbon dioxide in the atmosphere. This leads to global warming and the enhanced greenhouse effect. The consequences include melting of ice caps, glaciers, and permafrost, rise in sea levels, floods, droughts, and hurricanes.

4. Outline the threat to coral reefs from increasing concentrations of dissolved CO_2.

Increasing atmospheric carbon dioxide concentration leads to an increase in the amount of carbon dioxide dissolved in the ocean. This has caused the ocean to become more acidic because carbon dioxide reacts with water to form carbonic acid, which dissociates to form hydrogen ions and hydrogen carbonate ions. Hydrogen ions convert carbonate ions, which are required by coral to synthesise calcium carbonate for their skeletons, into hydrogen carbonate. As a result, coral grows more slowly as new calcium carbonate cannot be synthesised. Hydrogen ions can also react with the calcium carbonate skeletons of the corals and cause them to break down. Thus, an increase in the concentration of dissolved CO_2 threatens the existence of all reef ecosystems.

5.1 Evidence for Evolution

1. Describe using an example, how homologous structures provide evidence for evolution. [4m]

Homologous structures share similar structures while having different functions. For example, the pentadactyl limb in vertebrates all have a similar bone structure but perform different functions for locomotion. This suggests that they evolved from a common ancestor which had undergone evolution in a process known as adaptive radiation.

2. Outline the process of speciation. [4m]

Speciation is the process by which a species splits into 2 species. It occurs when groups in a species become reproductively isolated and diverge. Isolation is a result of geographical separation which can cause gene pools to separate. Speciation occurs over long periods as changes accumulate over time.

3. Outline the evidence for evolution provided by selective breeding. [3m]

Selective breeding is the process by which humans artificially select organisms with favourable characteristics from a wild population. All animals are domesticated by humans from wild species which has natural variation due to random mutation. Thus, some organisms possess desirable traits over others and are selected and allowed to breed and pass on the traits to their offspring, helping to eliminate undesirable characteristics. For example, the broccoli which has the traits to suppress flower development was developed from the wild mustard species. Selective breeding can cause rapid changes in the original species over time and hence cause evolution.

4. Outline how fossil evidence supports the theory of evolution.

The fossil record provides evidence to show that life on earth has changed over geological time. Life forms that previously existed do not exist anymore due to evolution. The age of the fossils can be determined by dating the rock using radioisotopes. Fossilised organisms increase in complexity and diversity from older to newer rocks. Additionally, sequences of progressively younger fossils can be found which show cumulative changes over time.

5. How does the presence of melanistic varieties of moths in polluted areas support the theory of evolution?

The peppered moth (Biston betularia) is a light coloured moth that rests on tree trunks with lichens on its surface which helps it to camouflage, decreasing the chance of predation. Mutations in the species produce a melanistic, dark coloured moth. Coal-burning during the industrial revolution caused trees to be covered with a layer of dark soot and the sulfur dioxide in the air killed the lichens. As such, the melanistic moths were better able to camouflage and avoid predation while the peppered moths were more likely to be eaten. Over time, the melanistic variety of moths increased due to natural selection and survival of the fittest while the peppered moth became rare, therefore supporting the theory of evolution.

5.2 Natural selection

1. Outline how variation in organisms of the same species could lead to natural selection. [3m]

Organisms that have favourable variations are more likely to survive and pass on their favourable genes to offspring which results in natural

selection. Additionally, the environment may not be able to support all the organisms which cause competition for resources which results in survival of the fittest.

2. Explain how evolution occurs and which factors can cause the process to be rapid. [7m]

Evolution is a change in the hereditary characteristics of an organism. Evolution occurs as a result of natural selection which happens due to the environment being unable to support the number of organisms, which causes survival of the fittest. The organisms with favourable variations are more likely to survive and reproduce, passing down favourable genes to their offspring, causing a change in the gene pool Mutation and meiosis also leads to more variation and hence natural selection. The changes in an organism's environment such as an increase in rainfall or air pollutants, and artificial selection or selective breeding are factors that can speed up the process of natural selection and hence evolution.

3. Describe the evolution of antibiotic resistance in bacteria. [4m]

The evolution of antibiotic resistance in bacteria is a result of the excessive use of antibiotics. In any population of bacteria, natural variation occurs as a result of mutation. This caused some bacteria to be resistant to a specific antibiotic. These resistant bacteria are not killed by the antibiotic which allows them to survive and reproduce, passing down the resistance antibiotics to their offspring. Hence, the new population of bacteria are resistant to antibiotics.

4. Describe the consequence of the potential overpopulation of offspring. [5m]

The overproduction of offspring causes the environment to be unable to support the organisms as it has reached its carrying capacity. Thus, there is competition for resources as organisms struggle to survive. For example, the amount of food, nests or mates may be insufficient to support the increasing demand. Variation occurs in any population due to mutation, meiosis and sexual reproduction. Individuals which possess favourable variations are more adapted and likely to survive and reproduce, passing on the favourable genes to their offspring. Thus, the amount of favourable alleles in the population increases, leading to natural selection and hence evolution.

5. In a given population, some variations of a protein are expressed more frequently than others. Outline how evolution through natural selection can lead to the expression of one version of a protein than another. [6m]

Different alleles for proteins exist in nature which causes variations. Proteins which possess favourable variations are more likely to survive and are better adapted to a change in the environment, due to selection pressure which causes survival of the fittest, and natural selection. They reproduce and pass on the favourable allele to their offering. Thus the expression of the allele in the population increases and after a few generations, the characteristic of the species gradually changes.

6. Outline the causes of variation between individual members of a population.

- Mutation causes genetic variation. Gene mutations produce new alleles, and individuals may have different alleles of the same genes. Different combinations of alleles give different characteristics.
- Meiosis leads to new combinations of alleles in gametes, due to crossing over in prophase I and random orientation of chromosomes during metaphase I.
- Sexual reproduction leads to new combinations of alleles in zygotes, due to random fertilisation.

5.3 Classification of Biodiversity

1. Outline how species are named.

All species are named by the binomial system which is a universal system used by all scientists and is governed by an internationally agreed set of rules. This involves collaboration between international teams of scientists, which allows for universal recognition of species without the confusion of local names in different languages. The binomial system gives an organism two names: the first name is the genus name which starts with an upper case, and the species name, which starts with a lower case letter. For example, Homo sapiens is the binomial name for humans.

2. How are species classified by taxonomists?

Taxonomists classify species into a hierarchy of taxa. The taxa include the domain, kingdom, phylum, class, order, family, genus and species. As each division becomes smaller, the species become more similar to each other.

3. Name and outline the domains that all organisms are classified within.

Domains are the first division of organisms. All organisms are classified into 3 domains: Archaea, Eubacteria and Eukaryota. Archaeans include methanogen and halophiles. Eubacteria indude E. coli. Eukaryota include plants, animals and fungi. The organisms within the same domain share very general characteristics These domains were established by generating a cladogram using ribosomal RNA gene sequence. Viruses are not placed into any taxonomic domain as they are not classified as living organisms.

4. List the features that can be used to distinguish the following plant phyla: (i) Bryophyta, (ii) Filicinophyta, (iii) Coniferophyta, (iv) Angiospermophyta

- Bryophyta have no roots and only rhizoids. They have simple leaves and produce spores in a capsule. They do not have vascular bundles.
- Filicinophyta. have true roots, stems, and leaves. They have divided or pinnate leaves with vascular bundles and produce spores in sporangia. Their stems are short and non-woody.
- Coniferophyta have true stems, leaves, and roots. They have vascular bundles, their leaves are needle-like and their stems are tall and woody. They distribute via seeds which develop in cones.
- Angiospermophyta have true stems, roots, leaves, and flowers. Their leaves and stems vary and they have vascular bundles. They distribute via seeds that develop in ovaries and form fruits.

5. List the features that can be used to distinguish the following aminal phyla: (i) Porifera, (ii) Cnidaria, (iii) Platyhelmintha, (iv) Annelida, (v) Mollusca, (vi) Arthropoda, (vii) Chordata

- Porifera are asymmetrical, porous, and have no mouth or anus
- Cnidaria have radial symmetry, stinging cells on tentacles and a mouth but no anus
- Platyhelmintha are bilaterally symmetrical. They have a flat body with no segmentation and a mouth but no anus.

- Annelida are bilaterally symmetrical. They have a segmented body that is commonly bristled and have a mouth and anus.
- Mollusca are bilaterally symmetrical, have no segmentation and commonly have shells. They have a mouth and anus.
- Arthropoda are bilaterally symmetrical. They have segmented bodies and jointed appendages with legs and antennae. They have an exoskeleton.
- Chordata have a notochord, a dorsal nerve chord, pharyngeal slits and a post-anal tail.

6. List the features that can be used to distinguish between the following types of vertebrates: (i) Mammals, (ii) Birds, (iii) Amphibians, (iv) Reptiles, (v) Fish

- Mammals have skins covered with hair, different types of teeth and mammary glands. Their young are born alive and they are warm-blooded.
- Birds have skin covered with feathers and forelimbs which are modified into wings. They have a beak with no teeth and their young are hatched from eggs with hard shells and they are warm-blooded.
- Amphibians have moist and permeable skin. They lay eggs on land with soft shells and are internally fertilised. They are cold-blooded.
- Fish have skin covered with scales. Their limbs are modified into fins for swimming and they have gills for breathing. They lay eggs in water that are externally fertilised and are cold-blooded.

5.4 Cladistics

1. Define clade and how its members are determined.

- A clade is a group of related organisms which share a recent common ancestor.
- Each clade is determined by analysing the sequence of bases in a gene or amino acids in a protein. Species that have similar gene and protein sequences share a more recent common ancestor thus should be placed in the same clade. Species with many differences in their gene or protein sequence are less closely related and belong to different clades, as they share a less recent common ancestor.

2. Describe what is shown in a cladogram. [2m]

A cladogram shows the similarities and differences between organisms and the possible variations between the species. It also shows the common ancestry of species which is deduced from the common clades.

3. Why is the reclassification of species sometimes needed?

Reclassification of species is sometimes needed because they had previously been classified by their morphological features, For example the figwort family was classified based on its flower shape, which was too trivial. This feature resulted from convergent evolution as the plants adapted to similar pollinators. The use of cladistics is a better method of classification as it compares the DNA sequences between species and corresponds with their evolutionary relationship.

10.3 Gene pools and speciation

1. Define the term gene pool.

A gene pool is the collection of all the genes and the different alleles of those genes that exist in a freely interbreeding population.

2. Describe the changes that occur in gene pools during speciation. [5m]

A gene pool is the collection of all the genes and the different alleles of the genes that exist in a freely interbreeding population. During speciation, the gene pools diverge due to reproductive isolation, which can occur due to geographical, temporal, or behavioural isolation. The allele frequencies change as alleles determining more favourable characteristics will have an increase in expression. Random mutation occurs which produces natural variation, leading to natural selection. Speciation occurs when the two populations can no longer interbreed.

3. Outline the criteria that should be used to assess whether a group of organisms is a species. [3m]

The two organisms can interbreed to produce fertile offspring. The organisms have similar observed characteristics or phenotypes. They have the same types of chromosomes and the same chromosome number.

4. Describe the process of speciation.

Speciation is the process by which two populations of the same species become two separate species. Reproductive isolation occurs, through either geographical isolation, temporal isolation or behavioural isolation. The isolated populations are exposed to different selection pressures and alleles determining favourable characteristics will increase in frequency. This causes gene pools to change and the two isolated populations diverge so far from each other so that they can no longer interbreed, forming 2 separate species.

5. Explain how natural selection can lead to speciation. [7m]

In any population, natural variations occur between organisms due to meiosis, mutations and sexual reproduction. Some individuals may possess alleles that determine favourable characteristics, making them more adapted to the environment, causing survival of the fittest. As the environment is unable to support all the organisms due to overpopulation, there is competition for resources and the organisms with the alleles that determine favourable characteristics are more likely to survive passing down their traits to offspring. The change in the gene pool causes natural selection and hence speciation occurs. Speciation is the formation of new species from one population. Reproductive isolation must occur, which is due to geographical, behavioural or temporal isolation. The isolated populations are exposed to different selection pressures and the alleles determining favourable characteristics increase in frequency, due to natural selection. This causes changes in the gene pool and the two populations diverge until they can no longer interbreed, forming separate species.

6. Explain how polyploidy occurs and using a named example, how polyploidy can lead to speciation. [7m]

Polyploidy is the condition where an organism has more than 2 sets of homologous chromosomes and occurs due to the nondisjunction of chromosomes during meiosis. This causes gametes to be diploid, or have 2 sets of chromosomes. A haploid and diploid gamete can fuse to form triploid gametes, with 3 sets of chromosomes. Two diploid gametes can fuse to form tetraploid gametes, with 4 sets of chromosomes. Allium is a plant that is formed by polyploidy. Allium with diploid and tetraploid gametes can interbreed to form triploid

gametes, but they are infertile. Triploid gametes cannot undergo meiosis as the homologous chromosomes cannot pair up. Tetraploid gametes can form new species as they can pair with each other. Polyploids tend to be larger and may have a selective advantage.

7. Outline how reproductive isolation can occur in an animal population. [3m]

- Reproductive isolation can be sympatric or allopatric
- Temporal isolation occurs due to the timing of reproduction preventing interbreeding, for example, plants flowering at different times of the year.
- Behavioural isolation is due to differences in courtship behaviour, preventing interbreeding
- Geographical isolation occurs when a population is physically separated by a geographical barrier such as a river or mountain range, preventing interbreeding.

6.1 Digestion and Absorption

1. Outline how proteins are digested and the products of protein digestion absorbed in humans.

Proteins are digested by proteases. In the stomach, pepsin is secreted which digests proteins into amino acids. In the pancreas, the pancreatic juice is secreted which contains endopeptidase and trypsin which digest proteins into shorter chains of amino acids or peptides. The amino acids and short-chain peptides are absorbed in the walls of the small intestine via active transport into the bloodstream.

2. Describe the processes involved in absorbing different nutrients across the cell membrane of villus. [4m]

- Simple diffusion is the movement of nutrients down a concentration gradient. For example, fatty acids enter epithelial cells via simple diffusion.
- Facilitated diffusion is the passive movement of nutrients through channel proteins, down a concentration gradient. For example, fructose molecules enter epithelial cells via facilitated diffusion.
- Active transport is the movement of nutrients against the concentration gradient through a protein pump which requires ATP. For example, amino acids and glucose enter epithelial cells via active transport.

3. State the source, substrate, products and optimum pH conditions for amylase. [4m]

	Salivary amylase	Pancreatic amylase
Source	Salivary glands	Pancreas
Substrate	Starch	Starch
Products	Maltose	Maltose
Optimum pH	Neutral pH	Slightly alkaline

4. Outline the digestion, absorption, and assimilation of proteins in humans. [6m]

- Protein is a large molecule that needs to be broken down into smaller molecules before it can be absorbed and assimilated by the body. In the stomach, pepsin is secreted which digests protein into polypeptides. The gastric juice is acidic which provides an optimal environment for pepsin to act. In the pancreas, endopeptidase and trypsin is secreted which digests polypeptides into shorter chain polypeptides and amino acids. The pancreas has a slightly alkaline environment which is optimal for endopeptidase.
- The amino acids are absorbed into the epithelial cells of the small intestine by diffusion and active transport. The microvilli provide a large surface area to volume ratio which aids in the absorption. When amino acids enter the bloodstream, they are transported to the rest of the body to be assimilated. They enter the cells by active transport and diffusion and are used to synthesise proteins by ribosomes.

5. Describe the importance of hydrolysis in digestion. [6m]

Hydrolysis is the process by which the bonds within molecules are split with the addition of water. It is aided by enzymes and requires water. Hydrolysis is important as it helps to break down large molecules of food into simpler molecules which can be dissolved and absorbed by the small intestine into the bloodstream. An example is the hydrolysis of proteins to form amino acids, the hydrolysis of polysaccharides to monosaccharides and the hydrolysis of fats to fatty acids and glycerol. The monomers formed from hydrolysis are able to be transported across the wall of the small intestine and into the blood and lymph in the process of absorption.

6. Outline the role of peristalsis in the digestive system.

Peristalsis is a series of wave-like muscle contractions that move food down the digestive tract. It involves both the circular and longitudinal muscles in the walls of the intestine. Contraction of the longitudinal muscles help to push food forward while relaxation of the circular muscle in front of the food allows it to move forwards. Contraction of the circular muscles behind the food prevents it from moving backwards. Peristalsis occurs in the esophagus, stomach and intestines. Peristalsis helps to push food forward and mixes the food with digestive enzymes, increasing the rate of digestion.

7. Outline the role of enzymes secreted by the pancreas in digestion.

Digestion is the process by which large macromolecules are chemically broken down into their constituent monomers. This process is catalysed by digestive enzymes. In the pancreas, pancreatic juice is secreted which contains the digestive enzymes: amylase, lipase and endopeptidase. Amylase digests starch to maltose, lipase digests fats to fatty acids and glycerol while endopeptidase digests long chain polypeptides to short-chain polypeptides.

8. Outline the role of enzymes in the small intestine to complete the process of digestion.

The small intestine secreted enzymes to complete the process of digestion. Nuclease is an enzyme which digests nucleic acids to nucleotides. Dipeptidase digest dipeptides to amino acids. Maltase digests maltose to glucose. Lactase digests lactose to glucose and galactose. Sucrase digests sucrose to glucose and fructose. Exopeptidase digests short polypeptides into dipeptides and amino acids.

Cellulose is not digested but is egested in feces.

9. Describe the role of villi in the absorption of the products of digestion.

Absorption is the passage of monomers produced by digestion and other nutrients through the plasma membrane and into the bloodstream. Molecules pass through the epithelium which lines the inner surface of the mucosa. The mucosa is folded into projections called villi. The villi greatly increase the surface area of the epithelium. The outer membrane of epithelial cells are folded which produce microvilli. Microvilli increase the surface area for absorption further. The large surface area provided by the microvillar surface allows for a much faster rate of absorption. Within each villus, blood capillaries and a lacteal is present which helps to transport absorbed nutrients to the bloodstream.

10. Explain the digestion of starch in the small intestine.

Starch is made up of amylose and amylopectin. Amylose has 1,4 glycosidic bonds and is unbranched. Amylopectin has 1,4 and 1,6 glycosidic bonds and is branched. Amylase specifically catalyses the hydrolysis of 1,4 glycosidic bonds due to its active site. Digestion of amylose produces maltose while digestion of amylopectin produces maltose and dextrins. In the small intestine, maltase is secreted which digests maltose to glucose. Dextrinase digest dextrins to glucose.

11. Explain how the products of starch digestion are transported to the liver.

Glucose is absorbed through epithelial cells which line each villus, and passes into the blood capillaries within each villus. The capillary joins with a venule that connects it to the hepatic portal vein. The hepatic portal vein directly transports blood to the liver. In the liver, excess glucose is converted to glycogen for storage. Glucose uptake is controlled by the enzyme insulin.

12. Describe how maltose is digested and absorbed in the small intestine.

Maltose is digested by maltase, an immobilised brush-border enzyme in the epithelial cells of the small intestine. Maltose is received into

the active site of maltase, which hydrolyses the glycosidic bond in maltose and converts it to glucose. Glucose is a polar and hydrophilic molecule so it cannot pass through the plasma membrane by simple diffusion but requires facilitated diffusion. Sodium-potassium pumps in the membrane pump sodium ions from the cytoplasm to the interstitial spaces inside the villus and potassium ions in the opposite direction, creating a low concentration of sodium ions in the villus epithelium cells. Sodium-glucose co-transporter proteins in the microvilli transfer sodium ions together with a glucose molecule from the intestinal lumen to the cytoplasm of epithelium cells. Finally, glucose channels allow glucose to move by facilitated diffusion from the cytoplasm to the interstitial spaces inside the villus and on to blood capillaries in the villus.

13. Describe how a piece of protein is digested and absorbed in the small intestine.

A piece of protein is first digested by pepsin and pancreatic peptidase to oligopeptides and amino acids. Amino acids are transported via facilitated diffusion, from the lumen of the small intestine into the epithelial cells together with a sodium ion through an amino acid co-transporter protein. Immobilised brush-border peptidase digests oligopeptides into amino acids. Small oligopeptides are transported from the lumen of the small intestine into epithelial cells of the small intestine through an oligopeptide co-transporter, via facilitated diffusion. The amino acids are then transported from the interstitial spaces in the villus to the blood capillaries through an amino acid co-transporter via facilitated diffusion.

14. Describe how lipids are absorbed by the small intestine.

Lipids are emulsified by bile salts into small fat droplets which increases the surface area to volume ratio and facilitates digestion by lipase. Lipase digests fat droplets into fatty acids and glycerol. The fatty acids and glycerides diffuse into the epithelial cells of the small intestine, where they combine with bile salts to form spheres called micelles. The long-chain fatty acids and monoglycerides leave the micelles and combine to form triglycerides which form fatty globules that combine with proteins to form chylomicrons. The chylomicrons enable lipids to move in an aqueous environment without being exposed to water. They are extruded from the cell via exocytosis and enter a lacteal which transports chylomicrons away from the small intestine to the rest of the body.

6.2 The Blood System

1. Describe the function of the valves in the mammalian heart. [4m]

The valves in the heart helps to prevent backflow of blood in the heart. The opening and closing of valves help to control the timing of blood flow. For example, when the semilunar valves are shut, they allow the ventricles to fill with blood and rise in pressure rapidly. When the pressure in the ventricles exceeds the pressure in the aorta, the valves open, allowing blood to flow out.

2. Explain how circulation of the blood to the lungs and to other systems is separated in humans and what the advantages of this separation are. [8m]

The heart has a double circulation, the pulmonary circulation and the systemic circulation. The pulmonary circulation pumps deoxygenated blood to the lungs while the systemic circulation pumps blood from the heart to the rest of the body. The heart is split into 4 chambers: the right atrium and right ventricle on one side and the left atrium and left ventricle on the other. The left ventricle pumps blood from the heart to the rest of the body tissues via the aorta while the right ventricle pumps blood from the heart to the lungs via the pulmonary artery. The right atrium receives blood from the rest of the body which is deoxygenated while the left atrium receives blood from the lungs to the heart which is oxygenated. This separation is advantageous as it prevents the mixing of oxygenated and deoxygenated blood, increasing the saturation of oxygen in the blood. The difference in pressure of blood pumped from the atria and ventricles is advantageous. The lungs are of closer proximity to the heart thus require lower pressure thus the separation of the circulation is advantageous.

3. Describe the action of the heart in pumping blood. [5m]

The sinoatrial node is a specialised group of muscle cells in the right atrium of the heart, which acts as a pacemaker, sending electrical signals to the heart muscles causing them to contract. The atria fill with blood from the veins. Electrical impulses stimulate the walls of the atria to contract which is atrial systole. The blood flows from the atria to the ventricles as the AV valves are forced open. The semilunar valves remain shut which allows the ventricles to fill with blood. During ventricular systole, the ventricles contract. The semilunar valves are forced open to allow blood to flow into the pulmonary artery and aorta. The AV valves close to prevent backflow of blood. When the ventricles and atria relax, the semilunar valves close to prevent backflow of blood into the ventricles.

4. Outline the rate at which the heartbeat is controlled. [6m]

The cardiac muscles of the heart are myogenic, so they contract on their own without nerve signals sent from the brain. The heartbeat is

controlled by the sinoatrial node, a specialised group of cells located in the walls of the right atrium of the heart. It acts as a pacemaker by regulating the heart rate. It sends out electrical signals which stimulate the contraction of the heart muscles. The electrical signals pass through the walls of the atria and then to the AV node, which passes through the walls of the ventricle. The SA node is connected to the medulla oblongata of the brain via 2 nerves, the parasympathetic nerve which slows down the heart rate, and the sympathetic nerve which speeds up the heart rate. Epinephrine is a hormone that causes more signals to be transmitted along the sympathetic nerve, speeding up heart rate and preparing the body for vigorous activity.

5. Blood is a liquid tissue containing glucose, urea, plasma proteins and other components. List the other components of blood. [5m]

Blood contrains dissolved oxygen and carbon dioxide, erythrocytes, leucocytes, lymphocytes, amino acids, phagocytes, platelets, hormones and mineral ions.

6. What did William Harvey discover about the movement of blood in the body?

William Harvey found that blood is pumped by the force of the heart and only in one direction. The blood circulates continuously around the body as it is pumped in high volumes. The arteries pump blood away from the heart and the veins pump blood towards the heart. The capillaries link arteries to veins.

7. Describe the function of the arteries and how their structural features link to their function.

Arteries transport blood at high pressure from the heart to the body tissues. The arteries have a thick wall which includes a thick tunica externa containing collagen fibres which enables the artery to withstand high pressure. The arteries have a thick tunica media with elastic fibres and muscle. Elastic fibres stretch when the ventricles contract. The elastic recoil help to maintain high blood pressure between each contraction, keeping blood flowing through the artery. The smooth muscles in the arterial wall contract and relax, maintaining the diameter of the lumen to control blood flow through the artery. The artery has a narrow lumen which helps to maintain the high blood pressure.

8. Describe the function of capillaries. How do their structural features link to their function?

Capillaries link the arteries to the veins. Blood is transported through body tissues in the capillaries. The capillary wall is made up of a thin layer of endothelial cells which shortens the diffusion pathway, increasing the rate of diffusion. The capillaries have a narrow lumen which enables them to fit into small spaces. The pore between cells enables plasma to leak out of capillaries to form tissue fluid. Body cells are bathed in tissue fluid, which contains dissolved oxygen and nutrients, which diffuses into body cells. Waste materials diffuse from the body cells into tissue fluid which reenters the capillaries.

9. Describe the function of veins. How do their structural features link to their function?

Veins transport blood from the rest of the body to the heart at low pressure. Veins have a thin wall which enables veins to be compressed by contraction of the neighbouring muscles, helping to push blood back to the heart. The thin tunica externa of veins is due to low pressure of blood in veins. Veins have thin tunica media with reduced amounts of elastic fibres as the veins do not distend and the blood flowing through veins do not pulsate. Veins have a wide lumen relative to its size as blood flows slowly. Veins have valves which prevent the backflow of blood.

10. What are the causes of narrowing of the coronary arteries and how does this affect the body?

Fatty deposits can accumulate in the wall of the coronary artery, forming an atheroma which bulges inwards, narrowing the lumen of the artery. A tough coat develops on the outer surface of the atheroma due to calcium salt, forming a hardened plague. Narrowing, or occlusion of the coronary arteries is known as coronary heart disease, or atherosclerosis. It restricts blood flow to the heart, causing chest pain due to the heart being depleted of oxygen, known as angina. The factors which are suggested to cause CHD are smoking, diabetes, high LDL cholesterol levels, family history of heart disease and high blood pressure.

11. Describe double circulation and its advantages.

Double circulation involves two separate circulations in the body. The pulmonary circulation transports deoxygenated blood from the right ventricle to the lungs and returns oxygenated blood from the lungs to the left atrium. The systemic circulation transports oxygenated blood

from the left ventricle to the rest of the body and returns deoxygenated blood to the right atrium. Each red blood cell passes through the heart twice for a complete double circulation. Having a double circulation means that blood pressure can be modified for each circulation. The systemic circulation has a much higher pressure to supply all body tissues with oxygenated blood. The pulmonary circuit has a lower pressure to avoid damage to lung capillaries.

6.3 Defence against Infectious Diseases

1. Outline the body's first line of defense against infectious disease.

The first level of defense is the skin and mucous membranes. Their role is to prevent infectious pathogens from entering cells and tissues of the body. The skin acts as a tough physical barrier composed of dead cells that prevent entry. Sebaceous glands secrete lactic acid and fatty acids onto the skin's surface providing an acidic environment, reducing the growth of pathogens. Mucous membranes line body cavities in the ventilation, digestive and urinary systems. They are not tough physical barriers. Mucous is secreted by the membrane, a sticky substance that can trap pathogens. Mucous also contains lysozyme, an enzyme that digests bacteria.

2. Describe the process of blood clotting. [4m]

A rapid sequence of events is triggered following damage to the blood vessels to promote clotting of the blood to seal the wound site. Clotting factors are released by the damaged tissues, which converts inactive prothrombin to thrombin. Thrombin is an enzyme which converts soluble fibrinogen to insoluble fibrin. Fibrin forms a network of long fibres across the wound site which traps red blood cells, forming a clot.

3. Outline the role of phagocytes.

Phagocytes are a part of the body's second line of defense against infectious disease. They are a type of white blood cell which digests pathogens by phagocytosis, a type of endocytosis. Pathogens are enveloped by the plasma membrane of the phagocyte and contained within a vesicle in the pathogen. The cytoplasm of the phagocyte contains lysozyme, a digestive enzyme which breaks down pathogens by fusing with the vesicle. Phagocytosis is a form of non-specific immunity as they can ingest any form of pathogen.

4. Describe the production of antibodies by lymphocytes.

Lymphocytes are the body's third line of defense against infectious disease. They provide the most complex and specific immunity. Lymphocytes are a type of white blood cell which produces antibodies, which are secreted in response to any specific antigens present on pathogens. Antigens are any non-self molecules which enter the tissues or blood stream, triggering antibody producion. Antibodies are initially embedded within the plasma membrane of the lymphocyte. The antibodies on one lymphocyte will bind specifically to one antigen. Antigen binding activates the lymphocyte, causing it to divide rapidly by mitosis, producing many clones of the same lymphocyte. Some of the lymphocytes become plasma cells which specialise in secreting antibodies. The released antibodies will bind to pathogens with the specific antigen and stimulate phagocytes to ingest them. The other lymphocytes will become memory cells, which provide long term immunity. When the pathogen with the same antigen enters the body again, memory cells will recognise this and rapidly divide by mitosis to produce more plasma cells which secrete the specific antibodies.

5. How does HIV affect the immune system? How is HIV transmitted?

- HIV infects and destroys a specific type of lymphocyte which is needed for the production of antibodies. Over several years, the number of lymphocytes drop. AIDS is when the person can no longer produce any antibodies, which makes them very vulnerable to infections which a healthy person can fight off with ease.
- HIV is transmitted from one infected person to an uninfected person via unprotected sex, from mother to child via breast feeding, sharing of needles or blood transfusions.

6. Discuss the cause, transmission and social implication of AIDS. [8m]

- AIDS is caused by HIV which is a retrovirus that infects helper T lymphocytes, disabling the body's adaptive immune system. Over several years, the number of lymphocytes decrease, antibodies are unable to be produced, resulting in lowered immunity. The body becomes susceptible to opportunistic infections. AIDS is the observed syndrome when final stages of infection develop.
- HIV is transmitted through unprotected sex, sharing of hypodermic needles by drug users and blood transfusions.
- The treatment of AIDS is expensive and there is discrimination against AIDS victims. AIDS is also more prevalent in poorer countries, so there is a moral obligation of wealthier countries to help poorer countries.

7. Outline the use of antibiotics.

- Antibiotics are compounds that kill or inhibit the growth of microbes such as bacteria by targeting prokaryote metabolism. Metabolic features that are targeted by antibiotics include key enzymes, 70s ribosomes and components of the cell wall. Eukaryotic cells do not possess these features so are unaffected. For example, some antibiotics target only 70s ribosomes so specifically inhibit protein synthesis in prokaryotes.
- Through gene mutations, some bacteria have evolved resistance to antibiotics, which poses a great risk to human health. Viruses cannot be targeted by antibiotics as they do not have their metabolism, but rely on the metabolism of their host cell.

8. Comment on the credibility of studies to test penicillin on mice by Florey and Chain.

Penicillin was discovered by Alexander Fleming. Florey and Chain conducted drug trials on mice to test if penicillin could be used on humans. Florey and Chain infected eight mice with the bacterium that causes pneumonia. Four of the mice were treated with penicillin. The mice not treated with penicillin died while the mice treated with penicillin recovered. While showing that the drug is effective, it was trialled on a small scale which may not be representative of the actual effectiveness.

6.4 Gas Exchange

1. Describe the pathway that air takes from the mouth to the alveoli.

Air enters through the mouth, then through the trachea. It then passes through the bronchus, which is split into several bronchioles, before reaching the alveoli at the ends of each bronchiole.

2. What is the role of ventilation in gas exchange?

Body cells require oxygen for aerobic respiration and carbon dioxide is a waste product which needs to be removed. Gas exchange occurs at the tips of the bronchioles, in the alveoli. Blood becomes oxygenated as it flows through the lungs and carbon dioxide is excreted. Alveoli

are surrounded by a dense network of capillaries, through which blood is constantly moving. Oxygen moves by simple diffusion from the air spaces in the alveoli to the capillaries. Carbon dioxide diffuses from the capillaries into the air spaces in the alveoli. Ventilation helps to maintain the concentration gradients for oxygen and carbon dioxide into and out of the alveoli.

3. Outline how ventilation in humans ensures a supply of oxygen. [4m]

Ventilation is the exchange of gases between the lungs and air. During inhalation, the external intercostal muscles and diaphragm contract. The diaphragm flattens, causing the ribcage to move upwards and outwards. The thoracic volume increases causing the pressure inside the lungs to decrease. Air fills the lungs and brings fresh oxygen into the capillaries. The concentration of oxygen in the alveolar sacs is greater than that of the blood capillaries, causing oxygen to diffuse down a concentration gradient into the capillaries.

4. Outline the mechanism of ventilation in the lungs. [6m]

- During the inhalation, the external intercostal muscles contract and the internal intercostal muscles relax. The diaphragm contracts and flatterns, causing the ribcage to move upwards and outwards. The thoracic volume increases, causing the pressure in the lungs to decrease. Air flows into the lungs as the atmospheric pressure is higher.
- During exhalation, the internal intercostal muscles contract and the external intercostal muscles relax. The diaphragm relaxes and arches upwards into a domed shape, causing the ribs to move downwards and inwards. The thoracic volume decreases and the pressure in the lungs increases. Air flows out of the lungs until the pressure in the lungs is equal to atmospheric pressure.

5. Describe the features of alveoli in human lungs that adapt them for efficient absorption of oxygen. [6m]

There is a large number of alveoli which increases the surface area for faster rate of diffusion. The alveoli are surrounded by a dense network of capillaries which helps to maintain the steep concentration gradient of oxygen. The walls of the alveoli are one cell thick, which decreases the diffusion pathway for oxygen, increasing the rate of diffusion. The alveoli have a film of moisture on its surface which allows gases to dissolve in it.

6. Outline the roles of type I and type II pneumocytes.

- Type I pneumocytes are epithelial cells in the walls of the alveoli. They are flattened and extremely thin which minimises the diffusion distance for gases, increasing the rate of diffusion.
- Type II pneumocytes secrete a solution containing surfactant that lines the inner surface of the alveoli. The surfactant is amphiphatic, so it prevents the insides of the alveolus adhering to each other by reducing surface tension.

7. Describe what happens in alveoli. [4m]

Gas exchange occurs in the alveoli. Oxygen diffuses from the air spaces in the alveoli to the blood capillaries while carbon dioxide diffuses from the blood capillaries into the alveoli. The blood flow through the capillaries help to maintain a steep concentration gradient between gases. During exhalation, the volume of the alveoli decreases as air flows out. Type II pneumocytes secrete a surfactant which prevents the sides of the alveoli from adhering.

8. Adult humans may absorb more than five hundred litres of oxygen per day. Explain how gas exchange is maintained in the human respiratory system. [7m]

Ventilation is the exchange of gases between the lungs and blood capillaries. During inhalation, the external intercostal muscles and the diaphragm contracts, drawing air with high concentration of oxygen into the lungs. The alveoli are surrounded by a network of dense capillaries, through which blood constantly flows through, maintaining the concentration gradient of gases between the lungs and blood capillaries. Oxygen diffuses from the alveolar air spaces to the blood capillaries down a concentration gradient while carbon dioxide diffuses from the blood capillaries into the alveolar air spaces. The large number of alveoli increases the surface area for diffusion while the walls of the alveoli are one cell thick, shortening the diffusion pathway to increase the rate of diffusion. The type II pneumocytes secrete a surfactant which helps to reduce surface tension which prevents the alveoli from collapsing. The alveoli lining is moist which allows gases to dissolve, increasing the diffusion rate.

9. Describe the structure of the ventilation system, including the alveoli. [8m]

Ventilation is the exchange of gases between the lungs and blood capillaries. The trachea divides to form 2 primary bronchi. Each bronchi enter each lung and further branch until there are a large number of tiny bronchioles. Each bronchiole terminates in an elongated space enclosed by alveoli. The trachea and bronchi have ciliated epithelium which help to sweep foreign particles out of the airways, preventing them from entering the lungs. The alveolus is a tiny air sac with a diameter of about 100 μm. There is a large number of alveoli in the lungs which provides a large surface area for diffusion of gases. The cells in the alveolar wall are very thin which minimises the diffusion pathway of gases. The alveoli are surrounded by a dense network of capillaries which help to maintain the concentration gradient of gases for diffusion. The alveoli wall have Type II pneumocytes which secretes a surfactant that reduces the surface tension, preventing the alveoli from collapsing.

10. Outline the causes of lung cancer and its effects on the body.

The causes of lung cancer include smoking, due to the tobacco smoke containing carcinogens, asbestos fibres which can cause asbestosis, air pollution, certain infections and genetic predispositions. The effects of lung cancer on the body include persistent cough, shortness of breath, weight loss, coughing up blood, regular chest infections and feeling tired. If the cancer mass compresses adjacent organs it can cause chest pain, difficulty swallowing and heart problems.

11. Outline the causes of emphysema and its effects on the body.

Emphysema is a lung condition whereby the walls of the alveoli lose their elasticity due to damage to the alveolar walls. The loss of elasticity leads to abnormal enlargement of the alveoli, which results in a lower total surface area for gas exchange. The main causes of emphysema include smoking and air pollution. Smoking leads to bronchitis due to the build up of mucous in the lungs. This causes the number of phagocytes in the lungs to increase. Phagocytes secrete enzymes which break down elastic fibres in the walls of the alveoli, thus resulting in emphysema. The effects of emphysema on the body include shortness of breath, phlegm production, expansion of the ribcage, cyanosis and increased susceptibility to chest infections.

6.5 Neurons and Synapses

1. Outline how neurons generate a resting potential. [4m]

Resting potential is the potential difference across the plasma membrane of a neuron when it is at rest. Resting potential is generated by sodium-potassium pumps in the plasma membrane. Using ATP, they actively pump 3 Na+ ions out for every 2K+ ions they pump in. This generates a concentration gradient for sodium and potassium ions across the membrane. More positive charges are on the outside of the neuron than on the inside of the neuron, thus the inside is negative relative to the outside. Potassium ion leakage channels can further contribute to the inside being more negative. The membrane is polarised, as there is an unequal distribution of charge. The membrane has a potential difference of -70mV.

2. What is an action potential?

An action potential is a rapid change in charge across the membrane that occurs when a neuron is firing. Neurons contain ion channels that open or close in response to stimuli. Upon a stimulus, chemically-gated ion channels open, causing the membrane potential to increase to -50mV, the threshold potential. This triggers voltage-gated sodium ion channels to open, allowing sodium ions to rapidly diffuse down their concentration gradient into the neuron. This causes the inside of the neuron to become more positive and the membrane becomes more depolarised. When the inside of the membrane becomes more positive relative to the outside, the voltage-gated Na+ ions close. Following this, the voltage-gated K+ ions open, causing K+ ions to rapidly diffuse down their concentration gradient out of the neuron. This repolarises the neuron, causing the inside to become negative relative to the outside. Before another action potential can be triggered, a resting potential must be re-established, achieved by the action of sodium-potassium pumps.

3. Explain how an impulse passes along the axon of a neuron. [8m]

A nerve impulse is an action potential that is propagated along the entire length of the neuron, away from the cell body. Local currents are formed from the diffusion of sodium ions along the inside and outside of the axon membrane in opposite directions. When a region of the membrane is depolarised, some of the sodium ions that diffused into the neuron diffuse along the inside to the next region of the axon which is at resting potential. On the outside of the axon, some sodium ions diffuse from the region at resting potential back to the depolarised region. This causes the next region of the axon to reach threshold potential, about -50 mV and triggers an action potential. The voltage-gated ion channels open, depolarising the next region of the axon. Thus, local currents help each region of the axon to reach threshold potential, allowing action potentials to be propagated along the entire length of the neuron.

4. Outline saltatory conduction in myelinated axons.

Saltatory conduction is the process by which nerve impulses jump from one node of Ranvier to another. In myelinated axons, the nodes of Ranvier are the gaps between each myelin sheath. Depolarisation only occurs at the nodes of Ranvier, thus saltatory conduction greatly increases the speed of transmission of a nerve impulse along the axon.

5. Define what is a synapse.

Synapses are junctions between two neurons, between a neuron and receptor, or between a neuron and muscle cell.

6. What is the role of neurotransmitters?

Neurotransmitters allow communication between the two cells on either side of the synaptic cleft. Nerve impulses cannot travel across the synaptic cleft.

7. Describe the mechanism of synaptic transmission / Explain how nerve impulses pass from one neuron to another neuron. [8m]

An action potential travels to the presynaptic knob of the presynaptic neuron. Voltage-gated ion channels open, allowing calcium ions to enter the neuron by facilitated diffusion. Calcium ions cause the vesicles containing neurotransmitters to move to the presynaptic membrane and fuse with it. Neurotransmitters are released into the synaptic cleft via exocytosis and diffuse to the postsynaptic membrane. The neurotransmitter binds specifically to the ligand-gated sodium ion channel proteins in the membrane of the postsynaptic membrane, causing them to open. This allows sodium ions to diffuse into the post-synaptic neuron and causing it to be depolarised. When the threshold potential of the postsynaptic neuron is reached, the nerve impulse is initiated which generates an action potential. The neurotransmitter is broken down by specific enzymes in the synaptic cleft and the ligand-gated sodium ion channels close.

8. Describe the secretion and reabsorption of the neurotransmitter acetylcholine

Cholinergic synapses join neurons to skeletal muscle and use acetylcholine as a neurotransmitter. Acetylcholine is synthesised from choline and acetyl CoA in the presynaptic neurone and packaged into vesicles. Upon the arrival of an action potential, the vesicles containing acetylcholine move to the membrane of the presynaptic neuron and fuses with it, releasing acetylcholine into the synaptic cleft via exocytosis. It travels across the synapse and depolarises the post-synaptic membrane by binding to the ligand gated sodium ion channels. Acetylcholinesterase is an enzyme found in the synaptic cleft which breaks down acetylcholine into choline and acetate. This prevents the acetylcholine from causing continuous depolarisation of the post synaptic membrane which would cause continuous muscle contractions. Choline is reabsorbed into the pre-synaptic neuron where it can be re-synthesised into acetylcholine.

9. Describe how neonicotinoid pesticides block synaptic transmission at cholinergic synapses.

Neonicotinoid pesticides have a similar three-dimensional shape to acetylcholine. They are able to bind to ligand-gated sodium ion channels on the post synaptic membrane but do not cause the channels to open. They cannot be broken down by acetylcholinesterase, thus they block the binding of acetylcholine to the channels. This prevents depolarisation of the post synaptic cell and hence causes the insect to be paralysed, killing it.

6.6 Hormones, Homeostasis and Reproduction

1. Describe (i) the endocrine system, (ii) hormones, (iii) homeostasis.

- The endocrine glands consist of a number of ductless glands that secrete hormones directly into the blood. Examples include, the pancreas, the adrenal glands, thyroid gland and pituitary gland.
- Hormones are chemical messengers (proteins or steroids) that cause a change in activity of target cells. They are transported in the bloodstream.
- Homeostasis is the maintenance of the body's internal environment, within certain limits, such as blood glucose level or temperature. When changes occur, negative feedback mechanism brings these factors back to original limits.

2. Explain the control of blood glucose concentration in humans. [8m]

Blood glucose concentration is controlled by the pancreatic cells through negative feedback mechanisms. When the concentration of glucose in the blood is high, the β-cells in the islets of Langerhans secretes insulin which stimulates the liver cells to take up glucose, converting it into glycogen which lowers the blood glucose concentration. Other cells are stimulated to absorb glucose and use it for respiration. Conversely, when the concentration of glucose in the blood is high, the α-cells in the islets of Langerhans secretes glucagon which stimulates liver cells to break down glycogen into glucose, releasing into the blood which raises the glucose level of blood.

3. Explain the control of body temperature in humans. [8m]

Normal body temperature (37°C) is regulated by negative feedback mechanism. The hypothalamus is the center of thermoregulation and sends out impulses to the body cells to increase or decrease temperature. When the temperature rises, sweat glands in the skin release sweat which helps to cool the body by evaporation from the surface of skin. Vasodilation of skin blood vessels occurs which transfers heat to the surface of skin, decreasing body temperature. When the temperature drops, shivering increases heat production in the muscles. Vasoconstriction of the skin blood vessels occurs, decreasing the transfer of heat to the skin which reduces heat loss to surroundings. Hair erector muscles contract, causing hair to stand which traps a layer of air on the surface of skin to retain body heat.

4. Outline what is meant by homeostasis. [4m]

Homeostasis is the maintenance of a stable internal environment within narrow limits, through negative feedback mechanisms. For example, the maintenance of blood glucose concentration, temperature and water.

5. Outline the causes of type I and type II diabetes and how they are treated.

- Type I diabetes is early onset diabetes and mostly affects younger people. It is caused by the destruction of β cells in the islets of Langerhans in the pancreas by the body's immune system. This results in the body's reduced production of insulin which causes blood glucose concentration to be unregulated. This can lead to constant thirst, excessive urination and undiminished hunger. Treatment of type I diabetes involves injecting insulin into the bloodstream daily, particularly when blood glucose concentration is high.
- Type II diabetes is late onset diabetes and is associated with risk factors such as obesity, lack of exercise, age and genetic

predispositions. It involves an immune deficiency or reduced response of target cells due to change in insulin receptors, resulting in the loss of control of blood glucose levels. The treatment for type II diabetes includes change to lifestyle such as reducing carbohydrates in the diet and regular exercise.

6. Describe the role of thyroxin in humans.

Thyroxine is a hormone secreted by the thyroid gland and has a role in regulating the body's metabolic rate, thus most of the body cells are targets. Thyroxine binding to target cells increases its metabolic rate, which helps to generate body heat. Thus, when body temperature is low, more thyroxine is released to increase the body's metabolic rate and increase body temperature. High body temperature decreases thyroxin release, decreasing the body's metabolic rate which lowers body temperature

7. Describe the role of leptin in humans.

Leptin is a hormone secreted by adipose tissues, whcih are fat storage cells. Leptin regulates the body's appetite by targeting the hypothalamus in the brain. When food intake increases, the amount of adipose tissues increase which releases more leptin into the blood. This causes the inhibition of appetite by the hypothalamus and hence reduced food intake.

8. Describe the role of melatonin in humans.

Melatonin is a hormone secreted by the pineal gland in the brain which regulates circadian rhythms, which are the body's built-in 24-hour activity cycles. The hypothalamus controls melatonin production. In the night, decreased light production causes more melatonin release which promotes sleepiness. During the day, light triggers decreased melatonin production which prepares the body for being awake.

9. What are the causes of jet lag and how can it be prevented?

Jet lag is caused by travelling across multiple time zones in a short period of time, especially when travelling eastwards. The circadian rhythms no longer match the 24-hour activity cycles of the destination, which can cause the person to feel sleepy in the day or awake at

night time of the new location. It takes a few days for circadian rhythms to adjust to the new location, by light synals transmitted to the hypothalamus to modify melatonin secretion. Melatonin pills can be taken at night time to help the circadian rhythm to adjust and reduce jet lag.

10. Outline sex determination in males and females.

All embryos go through the same initial stages of growth and development and embryonic gonads can either develop into ovaries or testes. The developmental pathway of the embryonic gonads and hence the sex of the baby depends on the presence of absence of the SRY gene located on the Y chromosome. SRY codes for a DNA-binding protein called TDF (testis development factor) which stimulates the expression of other genes that cause testis development. Thus, the presence of the SRY gene leads to the development of testis, causing the fetus to become a male. Conversely, the absence of the SRY gene in an embryo with no Y chromosomes leads to the embryonic gonads developing into ovaries, and the fetus becomes female. The embryo will be female by default, the expression of the SRY gene causes a change in gonad development.

11. Outline the roles of testosterone in males.

Testosterone is a male sex hormone that is secreted by the Leydig cells in the testes. It causes prenatal development of male reproductive structures by the embryo. It also causes the development of secondary sexual characteristics at puberty, such as sperm production, growth of the penis and testes, pubic, body and hair growth.

12. Outline the roles of progesterone and estrogen in females.

Estrogen and progesterone are female sex hormones. They cause prenatal development of female reproductive structures in the fetus. They also stimulate the development of secondary sexual characteristics during puberty, causing the enlargement of breasts, widening of hips and pubic and underarm hair growth.

13. What is the menstrual cycle?

The menstrual cycle starts in females at puberty and continues until menopause. In the first half of the 28 day cycle, a follicle is developed in the ovary and the lining of the uterus is prepared for possible implantation. On the 14th day, ovulation occurs. An oocyte is released into the oviduct. If it is not implanted or fertilised, the endometrium breaks down and is released through the vagina during menstruation. The events of the cycle are controlled by the pituitary hormones FSH and LH, and the ovarian hormones estrogen and progesterone. The cycle involves both positive and negative feedback mechanisms.

14. Outline the role of specific hormones in the menstrual cycle, including positive and negative feedback mechanisms. [8m]

The anterior pituitary glands secretes FSH which causes follicle development in the ovary. The follicle cells secrete estrogen which causes the endometrium to become vascularised and thickened. Estrogen inhibits the secretion of FSH by negative feedback and promotes the secretion of LH. LH stimulates the follicle cells to secrete more estrogen which promotes a surge in LH, through positive feedback mechanism. The LH surge causes ovulation. Following ovulation, LH causes the follicle to develop into a corpus luteum. The corpus luteum secretes progesterone and some estrogen, which help to maintain and thicken the uterus lining. High progesterone results in negative feedback on the pituitary, inhibiting LH and FSH secretion. If no embryo implants in the endometrium, the corpus luteum degenerates and no longer secretes progesterone and estrogen. Progesterone levels drop and allow FSH secretion. Menstruation occurs and the cycle begins again.

15. Outline the process of in vitro fertilisation (IVF). [6m]

IVF is a procedure for couples with fertility issues to have children. At the start of the menstrual cycle, drugs are given to stop ovulation by inhibiting the FSH and LH production. This stops the menstrual cycle. High doses of FSH are given which stimulates the ovaries to develop multiple follicles. When the follicles are fully developed, hCG is given to stimulate the follicles to mature. Mature eggs are then mixed with sperm in a culture dish to be fertilised. Prior to implantation, the female is given progesterone to thicken the endometrium lining.

16. Outline William Harvey's investigations into sexual reproduction.

The 'soil and seed' theory was proposed by Aristotle, who asserted that the sperm ('seed') formed an egg when ixed with menstrual blood

('soil'). This theory was a popular doctrine for years before it was debunked by William Harvey. He studied the sexual organs of a female deer after mating in order to identify the developing embryo, but could not detect a growing embryo. Thus, he concluded that Aristotle's theory was incorrect and that menstrual blood did not contribute to the development of a fetus.

9.1 Xylem Transport

1. Explain the process of water uptake and transport by plants. [8m]

The root hair cells of the plant absorb water from the soil via osmosis, down a water potential gradient. This gradient is generated by the active transport of mineral ions from the soil into root hair cell which makes the water potential inside the root hair cell lower than that of the soil. The water is transported up the xylem vessel from the roots to the leaves. Transpiration is the process by which water vapour diffuses out of the leaves, generating a pull that causes water to move up the xylem. Cohesion is the attraction force between water molecules while adhesion is the attraction between water molecules and the cellulose in xylem cell walls. This generates a surface tension, creating a negative pressure potential that pulls water up the xylem into the leaf. The xylem cell walls are thickened with lignin which helps prevent them from collapsing, The lumen of xylem vessels is narrow which helps to transport water up the xylem via capillary action.

2. Explain how tension forces are generated in leaf cell walls.

Due to their dipolarity, water molecules are attracted to hydrophilic surfaces of other materials. Adhesion is the force of attraction between water molecules and cellulose cell walls of leaf mesophyll cells. Water evaporates from the leaf mesophyll cells into air spaces within the spongy mesophyll. Adhesion between water and cellulose pulls water from the xylem to replace the lost water. The combination of evaporation and adhesion between water and cellulose generates a tension force that moved water via the xylem from the roots to the leaves.

3. Describe the adaptations of xylem vessels to their function.

Xylem vessels transport water and mineral ions from the roots to the leaves, replacing water lost via transpiration. Xylem vessels are long, thin continuous tubes. This allows them to transport water over long distances and with little obstruction to the movement of water. The

walls of xylem verses are thickened with lignin which reinforces the vessels, preventing them from collapsing when transporting water under tension. Pits in the sidewalls of xylem vessels allow water and mineral ions to enter and exit the xylem.

4. Describe how water is transported in angiospermocytes. [6m]

Water moves from the roots to the leaves via the transpiration stream and is transported in the xylem. The xylem vessel is a long, continuous tube which has lignified cell walls. The evaporation of water from the cell walls inside the leaf to the surroundings generates a transpiration pull. Water that is lost is replaced by water from the xylem. A low-pressure potential is created at the top of the xylem which pulls water up from the roots. The cohesion forces between water molecules allows water to be pulled up in a continuous column that does not break. Adhesion forces between water molecules and the cellulose cell walls of xylem generates a surface tension which enables water to be pulled upwards.

5. Explain the processes by which minerals are absorbed from the soil into the roots. [8m]

Plants absorb minerals in the form of mineral ions, such as nitrogen, phosphate and potassium. Mass flow of minerals dissolved in water causes movment through the soil. The minerals diffuse down a concentration gradient towards the roots and are absorbed into the roots by active transport. Transport proteins use ATP to pump mineral ions against their concentration gradient into the roots. The proton pumps export H+ ions out of the cells, generating a proton gradient which enables mineral ions to move in. The root hair cells have numerous mitochondria which provide ATP for active transport. The root hair cells are also highly branched which increases the surface area to volume ratio, facilitating absorption. Fungal hyphae intertwine with root hairs, forming mycorrhizae which have mutualistic relationships with the roots, helping to enhance the absorption of minerals into the cells.

6. Explain how abiotic factors affect the rate of transpiration in terrestrial plants. [8m]

- As the humidity of air increases, the rate of transpiration decreases. Increasing humidity causes the concentration gradient of water vapour between the air spaces in the leaves and the atmospheric air to become less steep, thus decreasing the rate of diffusion of water out of the cell and hence decreases the rate of transpiration.
- As the temperature increases, the rate of transpiration increases. Greater temperature causes the rate of diffusion of water molecules

out of the cell to increase as they possess more kinetic energy. The evaporation of water from mesophyll cells increases as more latent heat is available, thus increasing the rate of transpiration.

- As the wind speed increased, the rate of transpiration increases. Water vapour on the surface of leaves open; facilitating the movement of water molecules out of the leaves.

7. Describe how plants carry out gas exchange in the leaves. [5m]

Oxygen and carbon dioxide gas enter and exit the leaves through the stomata down a concentration gradient. Photosynthesis helps to maintain the concentration gradient, keeping the concentration of O_2 high and CO_2 low in the leaf. Guard cells open the stomata in light and close the stoma in the dart. Gases move through the air spaces in the spongy mesophyll and carbon dioxide dissolves in the moist lining on the surface of mesophyll cell walls.

8. Outline the adaptations of plant roots for absorption of mineral ions from the soil. [5m]

Mineral ions are absorbed from the soil into the roots via active transport, against a concentration gradient. The roots are highly branched and have root hair cells which provide a large surface area to increase absorption. Root hair cells have carrier proteins and many mitochondria to provide ATP for active transport. Fungal hyphae and the roots intertwine to form mycorrhizae which help facilitate absorption of mineral ions into the roots.

9. In hot, dry conditions, plants lose water rapidly due to transpiration. Explain how the structures and processes of the plant allow this water to be replaced. [8m]

Evaporation of water from leaf mesophyll cells creates a negative pressure potential that generates a transpiration pull. Water from the xylem is drawn up into the leaves by cohesion of water molecules to cellulose and capillary action. Cohesion of water molecules to each other generates surface tension and allows the water to be drawn up the xylem in a continuous column. The xylem have liquified walls which enables them to resist the tension. Water moves into the roots via osmosis, down a water potential gradient. Active transport of mineral ions into the roots creates a high solute concentration in the roots, enabling osmosis. The roots are highly branched and extensive with many root hair cells, increasing the total surface area to facilitate absorption into the roots. The leaves of the plant have a thick, waxy

cuticle which helps to reduce water loss from the surface, decreasing the rate of transpiration. The plants are also adapted to have reduced leaves such as spines which reduces the surface area for water loss. The leaves have few stomata or stomata in pits, and have hairs on the surface which help to reduce water loss to the surroundings. The plants also have OAM physiology to reduce water loss by only opening their stomata at night, decreasing the rate of transpiration.

10. How are desert plants (xerophytes) adapted to reduce water loss?

Xerophytes may have a thickened waxy cuticle which reduces water loss from the leaf surface. The leaf surface have a layer of hair which helps to trap moist air on the surface of the leaf and reduce diffusion of water vapour out of the leaf. The leaves may have reduced stomata which reduces the outlets through which water vapour can diffuse out of. The stomata can be sunken or in pits which traps a layer of moist air on the surface and reduce transpiration. The leaves may be reduced to spines or needles reducing the surface area which decreases transpiration. Rolled leaves help to decrease surface area and hence exposure of stomata to the air, reducing the water loss. The roots are deep and extensive, allowing them to absorb water from deep in the soil. The plants have OAM and C4 physiology, which causes them to open stomata only at night, creating a reserve of CO_2 to be released during the day while stomata are closed.

11. How are plants which grow in saline soils adapted to reduce water loss?

Plants that are adapted to grow in saline soils, found in salt marshes, are called halophytes. The habitats of halophytes may have high concentrations of Na^+ and Cl^- which would cause water to move out of the plants via osmosis, down a water potential gradient. Halophytes may have altered flowering schedule which causes them to flower at specific times, such as in the rainy seasons, to minimise salt exposure. Halophytes have cellular sequestration which enables them to sequester toxic ions and salts in the cell walls and vacuoles. Halophytes have tissue partitioning, in which they concentrate salts in particular leaves which are then shed. They may also restrict the entry of ions and salt at the roots. Certain parts of the plant such as the stem may contain salt glands which actively eliminate salt.

9.2 Phloem Transport

1. Outline the process used to load organic compounds into phloem sieve tubes. [3m]

Organic compounds such as sucrose and amino acids are actively loaded into phloem sieve tubes by companion cells. Sucrose and amino acids move by apoplastic or symplatic routes. In the apoplast route, sugars travel from cell walls of mesophyll cells to cell walls of companion cells, where a sucrose transport protein actively transports the sugar. In the symplast route, most of the sucrose travels between cells into the sieve tube through plasmodesmata which are connections between cells. High concentration of solutes in phloem leads to water movement by osmosis.

2. Explain how organic compounds are transported within plants. [7m]

Organic compounds such as sugars and amino acids are transported in the phloem sieve tubes by mass flow, from sources to sinks, such as leaves to roots. Organic compounds are loaded into sieve elements via active transport. This involves a proton-sucrose symport driven by a H+ gradient generated by a H+ pump. Active transport generates a high concentration of solutes in the phloem sieve tubes at the source, causing water to move down a water potential gradient via osmosis, into the phloem, from the xylem. This increase in volume of water creates a high hydrostatic pressure in phloem sieve tubes at the source. At the sinks, sucrose is unloaded by active transport, causing water to move to the xylem via osmosis, creating a low hydrostatic pressure. Due to the incompressibility of water, phloem sap moves from regions of high hydrostatic pressure to low hydrostatic pressure. Companion cells help with loading while plasmodesmata provide a path between sieve tubes and companion cells.

3. Outline the adaptations of sieve tubes to their function.

Sieve tubes are made of elongated sieve elements that are joined end-to-end. This forms long and continuous tubes that connect all parts of the plant. The sieve elements are connected by sieve plates which are porous, allowing phloem sap to flow between cells. Sieve elements have no nuclei and reduced organelles which maximises space for the translocation of materials. The sieve elements also have thick and rigid cell walls which are able to withstand the hydrostatic pressures that enable flow. Sieve tube elements are connected to companion cells by plasmodesmata, allowing some sugars to enter and leave the sieve elements. The plasma membrane of sieve elements have protein pumps which enable loading and unloading of sugars into sieve elements by active transport.

9.3 Growth of Plants

1. What are meristems?

Meristems are groups of undifferentiated cells which have the ability to continually divide by mitosis. In plants, there are apical meristems, lateral meristems and intercalary meristems. They allow the plant to have indeterminate growth.

2. Outline the growth of plant shoot apex. [4m]

The plant shoot apex is a meristem which means that the undifferentiated cells can continually divide by mitosis thus growth in shoots is indeterminate. Growth in shoots is controlled by hormones, such as auxin. Auxin stimulates growth at the shoot apex, inhibiting laterla shoot growth and phototropism which causes plants to grow towards the light. Leaf primordia begins to develop from the shoot apex, then further divide and differentiate to form mature leaves.

3. Explain the role of auxin in phototropism. [8m]

Auxin is a plant hormone that can regulate plant growth. Auxin efflux pumps can create concentration gradients of auxin in plant tissues. These pumps cause auxin to be pumped away from the source of light. Auxin stimulates gene expression for proteins that increase the elasticity of the cell wall, aiding cell elongation. Auxin also activates proton pumps that secrete H+ ions into the cell wall to break bonds between cell wall fibres to aid cell elongation. Cells away from the light have more auxin and elongate more.

4. Describe the response of the shoot apex to light.

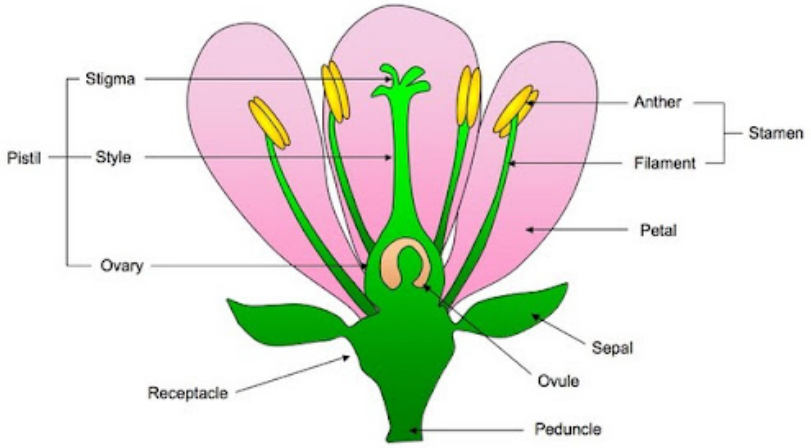
The shoot apex respone to light is called phototropism. Auxin is a plant hormone produced by the shoot apex and plays a role in phototropism. The shoot apex has phototropins which detect the direction of brightest light and regulates the transport of auxin. Auxin efflus pumps embedded in the plasma membrane can move within the membrane to change the distribution of auxin within the plant. When the shoot is exposed to light on one side, auxin efflux pumps move to the other side of the plant in the dark and actively transport auxin out of the cell. Auxin stimulates proton pumps in the plasma membrane to pump H+ into the cell wall, causing the pH to decrease. This causes the bonds between cell wall fibres to be broken and makes the cell wall extensible, allowing cell elongation. Thus, the cells on the dark side elongate which causes the plant to grow towards the light.

5. What are 3 advantages of micropropagation?

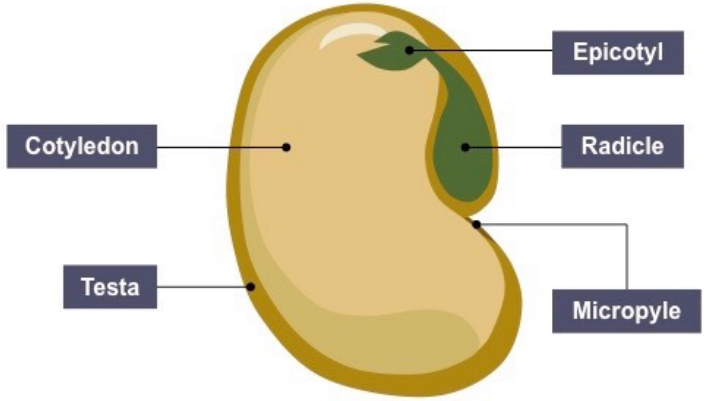
- Micropropagation is the propagation of plants from a very small sample of tissue.
- New plants can be rapidly produced in large numbers from a starting small amount of material.
- Virus-free plants can be produced.
- Orchids and other rare plant species can be produced.

9.4 Reproduction in Plants

1. Draw a half-view of an animal-pollinated flower. [4m]



2. Draw a labelled diagram of the internal structure of a seed. [3m]



3. Outline 3 processes required for successful reproduction of angiospermophyta. [3m]

Pollination which is the transfer of pollen from anther to stigma, fertilisation which is the joining of male and female gametes, and seed dispersal which is spreading seeds to new locations.

4. Outline the environmental stimulus that causes the switch to flowering.

The switch to flowering in most plants is determined by photoperiod. Photoperiod is the length of time within 24 hours a plant is exposed to light or dark, and can vary through changes in season. Plants are divided into long-day and short-day plants. The length of the dark period controls flowering. In long-day plants, flowering only occurs when dark periods are short, while in short-day plants, flowering only occurs when dark periods are long and uninterrupted. Phytochrome is a pigment in leaves and exists in an active form (P_{fr}) and inactive form (P_r). During periods of light, P_{fr} is rapidly formed while during periods of darkness, P_{fr} slowly reverts to P_r. In long-day plants, P_{fr} promotes flowering while in short-day plants, P_{fr} suppresses flowering.

5. Outline the metabolic processes that occur in starchy seeds during germination. [6m]

After the seed is imbibed with water, the metabolism is activated. Gibberillin is secreted which stimulates the production of amylase, an enzyme that catalyses the digestion of starch to maltose. Maltose is hydrolysed to glucose by the enzyme maltase. Glucose is used as the source of energy in aerobic respiration and used to synthesise cellulose for cell walls and other materials required for growth.

6. Outline the conditions needed for the germination of a typical seed. [3m]

Water is needed to rehydrate the seed and activate the metabolism. Oxygen is required for aerobic respiration as ATP is needed for growth. A suitable temperature is needed for the enzymes to have optimal activity.

7. Describe the processes of pollination, fertilisation and seed dispersal.

Pollination is the process by which pollen grains are transferred from the anther to the stigma of a flower. Animals, wind or water can facilitate this process. Fertilisation is the fusion of the male gamete contained within the male gamete and the female gamete in the ovule to form a zygote. Following pollination, a pollen tube grows down from the pollen grain to the ovule, where the nuclei of male and female gametes fuse during fertilisation. Fertilised ovules develop into seeds and the ovary matures into a fruit. Dispersal of seeds depends on the fruit.

11.1 Antibody production and Vaccination

1. Describe the activation of B cells in mammals.

B cells are activated by helper T cells as part of the primary immune response. This happens every time a new antigen is encountered. A macrophage ingests a pathogen by phagocytosis. The antigens from the pathogen are presented on the surface of the macrophage. Each helper T cell has a receptor protein in its plasma membrane with a unique antigen binding site. A helper T cell specifically binds to the antigen displayed on the macrophage, which activates it. B cells have membrane-bound antibodies on its surface which are unique. When an antibody on the surface of a B cell binds to a specific antigen, the antigen is ingested by endocytosis and presented on its surface. An activated helper T cell then binds to the antigen present on the surface of the B cell, activating it.

2. Describe events following the activation of B cells in response to a specific antigen.

Following activation, the B cells undergo repeated mitotic divisions to produce many clones of genetically identical B cells. Most divided B cells become plasma cells which secrete specific antibodies that bind to a unique antigen. These plasma cells only remain active for a few days. Other divided B cells become memory cells, which confer long-lasting immunity as they remain in the blood for a much longer period.

3. Outline how antibodies destroy pathogens.

Antibodies have two antigen-binding sites which differ between each antibody. By binding to antigens, antibodies can make pathogens more recognisable by phagocytes which have receptors that bind to the constant region of the antibody. Antibodies also cause pathogens to clump together, or agglutinate, making it easier for phagocytes to ingest. Antibodies activate proteins that causes lysis of the pathogen. Antibodies also block antigens from attaching to host cells.

4. Describe the function of immunoglobulins. [3m]

Immunoglobulins function as antibodies. They have variable binding sites and binds to specific antigens present on the surface of pathogens. The constant region aids in the destruction of the bacteria, by opsonisation. Antigens which bind to the constant region become more recognisable to phagocytes which digests them. Immunoglobulins also cause pathogens to agglutinate which makes it easier for phagocytes to ingest the pathogen by phagocytosis.

5. Explain the production and role of antibodies in defense against bacterial pathogens in humans. [8m]

Antibodies are produced in the specific immune response as a result of the presence of bacterial antigens. A macrophage ingests a bacterial antigen by phagocytosis and displays the antigens on its surface. This activates a T helper cell which causes it to bind to a B cell, activating it. Activated B cells then undergo repeated mitosis, producing many clones of genetically identical B cells. Most of the divided cells become plasma cells which produce the specific antibody for the antigen. The antibodies cause opsonisation and agglutination of phatogens which makes them more recognisable and easier for phagocytes to engulf. The plasma cells only remain in the blood for a few days. Some of the divided B cells differentiate to form memory cells which confer long lasting immunity.

6. Explain the principles of vaccination. [9m]

Vaccines contain the weakened or attentuated form of a pathogen and are either injected into a person or taken orally. The antigens stimulate a specific immune response called the primary response. The pathogens are ingested by macrophages by phagocytosis and the antigens are presented on the surface of the macrophage. The antigens stimulate helper T cells to bund to B cells with membrane bound antibodies on its surface which are specific to the antigen, achivating the B cells. Activated B cells undergo repeated mitotic divisions to form many clones of genetically identical B cells. Most of the divided B cells develop into plasma cells that secrete specific antibodies. Some of the divided B cells differentiate to become memory cells that confer long term immunity against the specific pathogen. The memory cells can stimulate the secondary response, that on second explore to the same pathogen the production of antibodies is much faster and in larger quantities. As the memory cells may not remain active for the person's lifetime, a booster shot may be required to maintain immunity.

7. Outline 3 factors that contributed to the eradication of small pox.

- Small pox is a human specific disease, so animals could not be infected and animal vectors or reservoirs coult not sustain the infectious agent.
- Small poc was easily identifiable as it had overt clinical symptoms which help to limit transmission
- The infection period was short-libed (3-4 weeks) and the virus was stable and did not mutate into alternate strains.

8. How are allergies caused?

Allergies are caused by the immune system overreacting to allergens. Allergens are foreign 'non-self' molecules that are not intrinsically harmful but act as antigens. A severe allergic reaction is called anaphylaxis and can be fatal if left untreated. An allergic reactiion requires a pre-sensitised immune state which is prior exposure to the allergen. When B cells encounter allergens, it differentiates to form plasma cells which produce large quantities of the IgE antibody. the IgE antibodies attach to mast cells, a type of white blood cell which is involved in the inflammation response. this causes them to release large amounts of histamine which causes inflammation and allergic symptoms such as sneezing and itching.

9. Describe the production of monoclonal antibodies.

Monoclonal antibodies are antibodies derived from a single B-cell clone. They are pure and only recognise a single antigen. In the process of monoclonal antibody production, an antigen is injected into a lab animal. The animal produces plasma cells that produce antibodies specific to the antigen. The plasma cells are removed from the animal and then fused with myeloma cells to form a hybridoma cell. The hybridoma cells are cultured separately and allowed to divide by mitosis, producing clones of hybridoma cells. Each clone of cells is tested with the original antigen and the cells which produce antibodies that bind to the antigen are identified. Clones of hybridoma cells secreting desired antibody are grown commercially on a large scale and large quantities of antibodies are purified.

11.2 Movement

1. How do bones and exoskeletons allow movement?

Movement occurs at joints, the connection between 2 bones. Muscles are anchored to bones and exoskeletons. Bones and exoskeletons act as levers which are rigid structures that enable a force to move a load. For example, flexing the forearm. The bicep is anchored to the top of the humerus and connected to the radius, at the point called the insertion. The joint is the fulcrum or pivot. Contracting the bicep causes the forearm to move. By having the insertion close to the joint, contraction of the muscle results in a large movement of the forearm.

2. Describe the antagonistic muscle pairs in an insect leg.

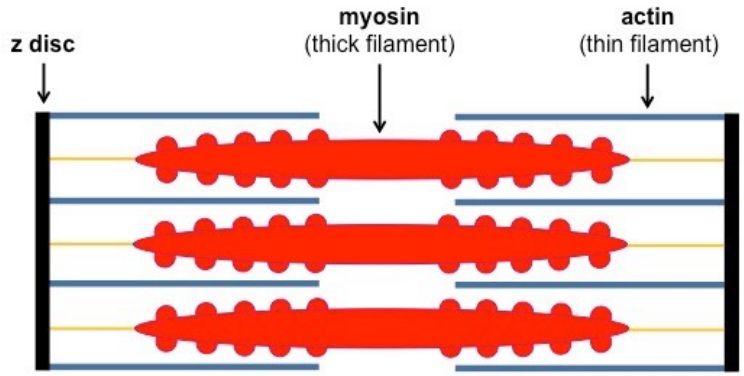
For a grasshopper to jump, the extensor and flexor muscles, a pair of antagonistic muscles in the exoskeleton, are needed to achieve flexing and extending limbs. The muscles are anchored to the femur. The tibia acts as the lever, with insertions from both muscles. When the leg is flexed to prepare to jump, the extensor relaxes and the flexor contracts. To jump, the extensor contracts and the flexor relaxes.

3. Describe the structure of skeletal muscle fibres.

Skeletal muscles are connected to bones via tendons and cause movement when they contract. Muscle tissue is comprised of long muscle fibres, which are specialised cells. Muscle fibres are multinucleate, have a large number of mitochondria, contain tubular myofibris made up of thin actin filament and thick myosin filament. The myofibrils are surrounded by sarcoplasmic reticulum which stores Ca+. The

sarcolemma is the plasma membrane.

4. Draw and label a diagram of a sarcomere. [5m]



5. Explain the process of muscle contraction. [8m]

Muscle fibres contain myofibrils which are made up of repeating units of sarcomeres. A sarcomere is made up of thin actin filaments and thick myosin filaments that are overlapping. A nerve impulse causes the sarcolemma to depolarise, triggering the release of calcium ions from the sarcoplasmic reticulum. Calcium ions bind to troponin which causes tropomyosin to move and expose binding sites on actin. Myosin heads bind to the sites on actin and form cross-bridges. Using energy from ATP, myosin heads swivel, causing the power stroke which moves the actin filament. Actin is moved towards the centre of the sarcomere, causing the sarcomere to shorten. ATP is used to break the cross-bridges between actin and myosin heads. The hydrolysis of ATP causes the myosin heads to become cocked. The cycle of events is repeated during muscle contraction.

6. Explain how calcium is involved in muscle contraction. [3m]

A nerve impulse depolarises the sarcolemma which triggers the release of calcium ions from the sarcoplasmic reticulum. Calcium ions bind to troponin which causes tropomyosin to move and expose binding sites on actin, allowing myosin heads to bind to them.

7. Distinguish between the two types of synovial joints.

The two types of synovial joints are the hinge joint and the ball-and-socket joint. The hinge joint only allows for one plane of movement while the ball-and-socket joint allows for many. The hinge joint allows for flexion and extension while the ball-and-socket joint allows flexion, extension, abduction and adduction. For hinge joints, the bones contact at one surface that is curved outwards and the other is grooved, while ball-and-socket joints contact at a ball that fits into a cup-shaped cavity. E.g. of hinge: elbow, knee; ball-and-socket: shoulder, hip

11.3 The kidney and osmoregulation

1. Distinguish between osmoconformers and osmoregulators.

- The internal solute concentration of osmoconformers is equal to the external solute concentration while the internal solute concentration of osmoregulators remains relatively constant and stable and is independent of the external solute concentration.
- Osmoconformers require less energy while osmoregulators require a large amount of energy
- Osmoconformers are unable to have optimal conditions for metabolic processes while osmoregulators allow for stable and optimal internal conditions for metabolic processes.

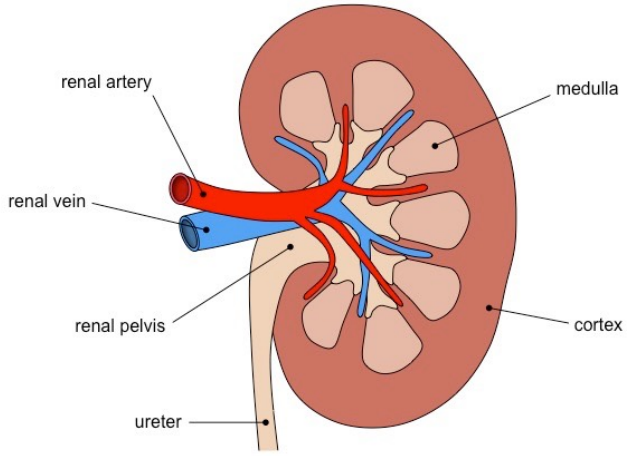
2. Describe the functions of the Malpighian tubul system of insects and the kidney.

The functions of the Malpighian tubule system of insects and the kidney include osmoregulation and excretion of nitrogenous wastes. Osmoregulation is the maintenance of solute concentrations of tissues and blood plasma within certain limits. Excretion of nitrogenous waste is the removal of breakdown products of excess amino acids from the body, which can be toxic if allowed to build-up.

3. Explain how insects excrete nitrogenous wastes. [8m]

In insects, nitrogenous wastes are excreted in the form of uric acid by the Malphigian tubules. Nitrogenous wastes accumulate in the hemolymph and are converted to uric acid. Uric acid is actively transported into the malphigian tubules as they have a high solute concentration. The tubules pass the uric acid along with some water to the hind gut, where they combine with digested food products. Water is reabsorbed by osmosis and returned to the hemolymph. The uric acid forms a solid paste and is excreted with faeces via the anus.

4. Draw a labelled diagram of the kidney and associated vessels. [5m]



5. Compare and contrast the composition of blood in the renal artery and renal vein, stating the reasons.

- Urea is lower in the renal vein than the renal artery as it is removed from the blood by ultrafiltration and excreted in urine
- Glucose is lower in the renal vein than the renal artery as it is reabsorbed
- Oxygen is lower in the renal vein than the renal artery as it is used during cell respiration of kidney tissues
- Carbon dioxide is higher in the renal vein as it is produced by respiring kidney tissues
- Ion concentration is lower in renal vein as excess is removed from blood and excreted
- Drug or toxins is lower in renal vein as it is excreted in urine

6. Explain how the structure of the glomerulus and Bowman's capsule assist in the process of ultrafiltration.

The glomerulus is encapsulated by the Bowman's capsule. Blood that flows through the glomerulus is under high pressure due to the afferent arteriole having a larger diameter than the efferent arteriole, allowing for filtration. The capillary wall of the glomerulus has pores or fenestrations that allow the passage of blood plasma out. The basement membrane surrounds the glomerulus and the inner wall of the Bowman's capsule surrounds the basement membrane. The inner wall of the Bowman's capsule contains podocytes which have foot processes that wrap around the glomerular capillary. The tiny foot gaps between the foot processes form filtration slits that allow blood plasma to be filtered and forms a filtrate. All dissolved substances in the blood plasma except plasma proteins pass through the filtration slits and enter the Bowman's capsule.

7. Describe the role of the proximal convoluted tubule.

The proximal convoluted tubule (PCT) is a long tube with one-cell thick walls. The PCT selectively reabsorbs all of the glucose and amino acids and about 80% of the mineral ions from the glomerular filtrate. The cells of the pct has a brush border of microvilli which increases the surface area for reabsorption. The walls are also one-cell thick and have many mitochondria, protein pumps and carrier proteins to facilitate active transport. As solutes are actively transported into the cells of the PCT, the solute concentration increases. Thus, water in the glomerular filtrate enters the cells in the PCT via osmosis. The materials actively transported into the cells of the PCT diffuse across the basolateral membrane into the blood capillaries which transports it to the bloodstream.

8. Describe the role of the loop of Henle.

The loop of Henle plays a role in osmoregulation, maintaining a hypertonic environment in the medulla by means of a countercurrent multiplier mechanism. The loop of Henle consists of a descending limb and ascending limb. The descending limb is permeable to water but not the salts. When filtrate passes through, reabsorption of water occurs through aquaporins in the membrane of the loop of Henle. Water moves out of the descending limb into the surrounding blood capillaries by osmosis and the filtrate becomes increasingly concentrated. The ascending limb is permeable to salts but impermeable to water. As filtrate flows through the ascending limb, sodium and chloride ions are pumped out into the medulla via active transport. The filtrate becomes increasingly dilute as it flows through the ascending limb.

9. Describe the role of the collecting duct.

The collecting duct carries filtrate through the medulla to the renal pelvis, and it plays a role in osmoregulation. The walls of the collecting duct are permeable to water. An osmotic gradient exists between the filtrate in the collecting duct and the medulla as the medulla has a high concentration of solutes. Osmoreceptors in the hypothalamus of the brain detect the solute concentration of blood. When it is too high, ADH is released from the pituitary gland which increases the permeability of the walls of the collecting duct to water by upregulating the production of aquaporins, allowing more water to flow out of the collecting duct by osmosis. The blood solute concentration decreases and less water remains in the filtrate, producing a small volume of urine. When the person is overhydrated, no ADH will be secreted and less water is lost from the collecting duct, producing a larger volume of dilute urine.

10. What can urine test strips reveal?

Urine test strips can reveal the presence of glucose which indicates diabetes. High concentration of proteins in the urine indicates kidney disease. Blood cells in urine may indicate kidney disease, cancer, bladder infections or kidney stones. Test strips containing immobilised monoclonal antibodies can detect the presence of illegal drugs in urine.

11. What are the three types of nitrogenous wastes in animals?

- Ammonia is a toxic substance that requires a large volume of water to excrete and requires little energy to produce
- Urea is less toxic than ammonia so more concentrated solutions of urea can be produced. It requires more energy to convert ammonia to urea.
- Uric acid is not toxic and can be excreted with almost no water as it is insoluble. It requires a large amount of energy to b e converted from ammonia.

11.4 Sexual reproduction

1. Outline the events of spermatogenesis. [4m]

Spermatogenesis is the process by which spermatozoa is produced in the seminiferous tubules of the testes. The germinal epithelial cells of

the seminiferous tubules divide by mitosis to produce spermatogonia. Each spermatogonium grows to form a large cell, called a primary spermatocyte. Each primary spermatocyte undergoes the first meitotic division to form two secondary spermatocytes. The two secondary spermatocytes undergo the second meitotic division to produce 4 haploid spermatids. Spermatids attach to sertoli cells which help the spermatids differentiate into spermatozoa.

2. Describe the different cell types in the seminiferous tubules that are involved in the process of spermatogenesis. [4m]

Spermatogonia are diploid and undifferentiated germ cells. They enlarge to become large primary spermatocytes which are diploid. Primary spermatocytes divide by meiosis I to form haploid secondary spermatocytes, which undergo meiosis II to form haploid spermatids. Spermatids differentiate to form spermatozoa with help from sertoli cells.

3. Outline the events of oogenesis.

Oogenesis is the process by which an ovum is produced in the ovaries. The germinal epithelial cells undergo repeated mitosis to produce oogonia. Each oogonium enlarges to form a primary oocyte. Each primary oocyte undergo meiosis I but are arrested in prophase I when granulosa cells surround them to form follicles. These primary follicles remain dormant until puberty, when the menstrual cycle begins. Primary follicles develop due to the release of FSH, and meiosis I is completed. Each primary oocyte forms one large secondary oocyte and one small polar body due to the unequal division of the cytoplasm. The secondary oocyte undergoes meiosis II but is arrested at metaphase II. At ovulation, the secondary oocyte is released from the ovary by a mature follicle. The completion of meiosis II is triggered by the sperm fertilising the secondary oocyte. This produces a large ovum and a second small polar body due to the unequal division of the cytoplasm. The nuclei of the ovum and sperm fuses, forming a zygote. The polar bodies degenerate.

4. Compare and contrast the processes of spermatogenesis and oogenesis. [8m]

Spermatogenesis	Oogenesis

First division by mitosis in the germinal epithelium	
Cell growth before meiosis	
Undergo two divisions of meiosis	
Cells differentiate to produce a mature gamete	
In the testes	In the ovaries
Begins at puberty	Begins in the fetus
No pauses in meiosis	Pauses occur in prophase I & metaphase II
Cytoplasm splits equally	Unequal division of cytoplasm
Each primary spermatocyte produces 4 mature spermatozoa	Each primary oocyte produces 1 mature ovum
Millions of sperm produced daily	One mature ovum released per menstrual cycle
Unlimited and continual production	Stops at menopause

5. Distinguish between internal and external fertilisation.

- Internal fertilisation occurs inside the body while external fertilisation occurs outside the body.
- In external fertilisation, a male discharges sperm over the eggs while in internal fertilisation, a male discharges sperm into the female.
- External fertilisation is susceptible to environmental changes such as pH or predators while internal fertilisation prevents the exposure and dessication of gametes or embryos.

6. Describe the process of fertilisation.

When the sperm reaches the egg in the oviduct, the acrosome reaction is needed for sperm to break through the surrounding jelly coat. The sperm pushes through the follicular cells of the corona radiata and bind to the zona pellucida, initiating hydrolytic enzymes to be released which softens the glycoprotein matrix and allows the sperm to pass through. The sperm then binds to the docking proteins on the egg membrane. When the membrane of the egg and sperm fuse, and the nucleus of the sperm enters the egg, the cortical reaction is initiated. cortical granules within the egg's cytoplasm fuse with the egg membrane, releasing enzymes via exocytosis into the zona pellucida which destroys sperm binding sites and causes the glycoprotein matrix to harden, preventing polyspermy.

7. Outline the steps between fertilisation and implantation.

Following fertilisation of the egg by a sperm, meiosis 2 is completed. The egg and sperm nuclei fuse and the fertilised cell is a diploid zygote. The zygote undergoes meitotic divisions in the oviduct to become a morula. The morula differentiates to form a fluid filled ball of cells called a blastocyst. The blastocyst then implants in the endometrium for pregnancy to continue.

8. What is the role of HCG secreted by the embryo in early pregnancy?

From the blastocyst stage, the embryo secretes human chorionic gonadotropin (hCG). hCG helps to maintain the corpus luteum which secretes progesterone and estrogen. Progesterone maintains the endometrium lining while estrogen inhibits the production of LH and FSH, preventing menstruation. Later in the pregnancy, the placenta develops and takes over the role of the corpus luteum in secreting progesterone.

9. Explain how the structure and functions of the placenta maintain pregnancy. [8m]

The placenta is the site of exchange of materials between the fetal and maternal blood. Oxygen and nutrients travel from the maternal blood to fetal blood while urea, carbon dioxide and other waste products travel from the fetal blood to the maternal blood. The placenta has chorionic villi which increase the surface area for exchange. The spaces between chorionic villi are filled with maternal blood so fetal blood and maternal blood are in close proximity, shortening the diffusion pathway and increasing the rate of diffusion. The placenta has a barrier

that prevents maternal blood and fetal blood from mixing. The placenta is also an endocrine gland so it secretes hormones such as hCG, estrogen and progesterone. hCG helps to prevent the corpus luteum from degenerating. Progesterone maintains the endometrium as well as prevent uterine contractions. Estrogen increases mammary gland growth and uterine muscles.

10. Outline the roles of estrogen and progesterone in females during human reproduction. [4m]

Estrogen causes the uterine lining to become vascularised and thickened. At high levels, estrogen stimulates LH secretion which causes ovulation. Progesterone helps to maintain the endometrium during pregnancy. Estrogen and progesterone inhibit LH and FSH production after ovulation. A drop in progesterone during pregnancy triggers the release of oxytocin which causes contractions. Estrogen and progesterone cause pre-natal development of female reproductive organs and secondary sexual chracteristics at puberty.

11. Outline the roles of hormones at childbirth.

Close to birth, the level of estrogen is higher than the level of progesterone. Estrogen increases the sensitivity of the uterus to oxytocin by increasing the number of oxytocin receptors in the muscular wall. The level of progesterone drops before childbirth, triggering the release of oxytocin from the pituitary gland. Oxytocin stimulates the uterine muscles to contract and inhibits progesterone secretion. The foetus responds by releasing prostaglandins which trigger further uterine contractions, causing a positive feedback loop. Contractions stop when labour is complete and the baby is birthed.