Paper 1

B1 Cell Level Systems

B1.1 Cell Structures

B1.1a — Describe how light microscopes and staining can be used to view cells

1. The three main parts are the lenses, which magnify the specimen; the stage, which supports the specimen; and the lamp, which illuminates the specimen.
2. The lenses magnify the specimen, the stage supports the microscope slide, and the lamp provides light that passes through the specimen.
3. A thin specimen is placed on a microscope slide, a drop of liquid or stain is added if required, and a cover slip is carefully lowered over the specimen.
4. Stains are used to increase contrast, making colourless cells and their structures easier to see.
5. Different stains bind to particular cell structures or tissues, causing them to appear different colours and allowing scientists to distinguish between structures.
6. Total magnification = eyepiece magnification × objective magnification. For a ×10 eyepiece and ×40 objective: 10 × 40 = ×400.

B1.1b — Explain how the main sub-cellular structures of eukaryotic cells (plants and animals) and prokaryotic cells are related to their functions

1. The nucleus contains the cell's genetic material, which is organised into chromosomes. Chromosomes contain genes that provide instructions for making proteins and controlling cell activities.
2. In eukaryotic cells, genetic material is enclosed within a nucleus and arranged into linear chromosomes. In prokaryotic cells, genetic material is not enclosed in a nucleus and consists mainly of a circular DNA molecule in the cytoplasm.
3. Plasmids are small, circular DNA molecules found in prokaryotic cells. They carry additional genetic information, such as genes for antibiotic resistance.

4. Mitochondria are the site of aerobic cellular respiration, where energy is transferred to produce ATP. Their internal membranes provide a large surface area for reactions involved in respiration.
5. Chloroplasts are the site of photosynthesis in plant cells. They contain chlorophyll, which absorbs light energy needed for photosynthesis.
6. The cell membrane is a selectively permeable barrier that controls the movement of substances into and out of the cell and contains receptor molecules involved in cell signalling. Ribosomes are the site of protein synthesis.

B1.1c — Explain how electron microscopy has increased our understanding of sub-cellular structures

1. Resolution is the ability of a microscope to distinguish between two points that are close together as separate points.
2. A transmission electron microscope (TEM) has a much higher resolution than a light microscope, allowing much smaller structures to be distinguished.
3. A TEM uses a beam of electrons, which have a much shorter wavelength than visible light. This gives the electron microscope a much higher resolution.
4. Structures that can be seen in greater detail using an electron microscope include ribosomes and the internal membranes of mitochondria.
5. A light micrograph can show larger structures such as the nucleus, cell wall, chloroplasts and vacuole, whereas an electron micrograph can reveal much smaller structures and detailed internal organisation.
6. Electron microscopes have allowed scientists to observe smaller sub-cellular structures and their detailed internal organisation, improving understanding of how cell structures are arranged and how they relate to cell functions.

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B1.2 What happens in cells (and what do cells need)?

B1.2a — Describe DNA as a polymer

1. DNA (deoxyribonucleic acid) is the molecule that carries genetic information in living organisms.
2. A polymer is a large molecule made from many smaller repeating units called monomers.

3. DNA is described as a polymer because it is a large molecule made from many repeating nucleotide monomers joined together.
4. DNA is made up of repeating units called nucleotides.
5. In a eukaryotic cell, DNA is found mainly in the nucleus, where it is organised into chromosomes.
6. DNA is important because it stores genetic information, including the instructions needed to make proteins and control the characteristics and activities of cells.

B1.2b — Describe DNA as being made up of two strands forming a double helix

1. A DNA molecule consists of two strands.
2. A double helix is a structure consisting of two strands twisted around each other in a spiral shape.
3. DNA has the shape of a twisted ladder, with two strands forming the sides and paired bases forming the rungs.
4. The two DNA strands run alongside each other and are held together by bonds between complementary bases.
5. The two strands form a double helix.
6. The double helix provides a stable structure for storing genetic information while allowing the strands to separate when the DNA needs to be copied.

B1.2c — Describe experiments that can be used to investigate enzymatic reactions

1. An enzyme is a biological catalyst, usually a protein, that speeds up a chemical reaction without being used up.
2. An enzyme investigation could involve mixing an enzyme with its substrate under controlled conditions and measuring the rate of reaction, such as by measuring the time taken for a particular product to form or substrate to disappear.
3. The independent variable is the factor deliberately changed, such as temperature, pH or substrate concentration.
4. The dependent variable is the rate of the enzyme-controlled reaction, determined from measurements taken during the experiment.
5. Two control variables could be the volume or concentration of enzyme and the volume or concentration of substrate. Other factors, such as temperature or pH, may also need to be controlled depending on the independent variable.
6. Results can be recorded in a table, used to calculate reaction rates, and plotted on a graph to identify patterns and determine the conditions that produce the highest enzyme activity.

B1.2d — Explain the mechanism of enzyme action

1. Enzymes control metabolic reactions by acting as biological catalysts, increasing the rate of reactions in cells.
2. The active site is the specific region of an enzyme where the substrate binds and the reaction takes place.
3. The lock and key hypothesis states that an enzyme's active site has a specific shape that is complementary to its substrate, so only a particular substrate can bind effectively to that enzyme.
4. As temperature increases, enzyme activity generally increases until an optimum temperature is reached. Above the optimum, bonds maintaining the enzyme's structure can break, changing the shape of the active site and denaturing the enzyme. Enzymes also have an optimum pH; extreme pH values can alter the active site and reduce activity.
5. Increasing substrate concentration generally increases the reaction rate until all active sites are occupied and the enzyme becomes the limiting factor. Increasing enzyme concentration generally increases the reaction rate if sufficient substrate is available.
6. Enzymes are biological catalysts because they speed up metabolic reactions without being used up. Their specific active sites bind particular substrates, giving enzymes specificity. Enzyme activity is affected by factors including temperature, pH, substrate concentration and enzyme concentration.

B1 Cell Level Systems

B1.3 Respiration

B1.3a — Describe cellular respiration as a universal chemical process, continuously occurring in all living cells that supply ATP

1. Cellular respiration is a series of chemical reactions in cells that transfer energy from glucose to make ATP.
2. Cellular respiration is described as a universal chemical process because it occurs in all living organisms.
3. Cellular respiration occurs continuously in all living cells.
4. Cellular respiration supplies ATP (adenosine triphosphate), which provides energy for cellular processes.
5. Cells require a continuous supply of ATP because ATP is constantly used to provide energy for cellular processes and must therefore be continually resynthesised.

6. Cellular respiration must occur continuously because cells constantly require energy for processes such as active transport, movement, growth and synthesis, even when an organism is resting.

B1.3b — Describe cellular respiration as an exothermic reaction

1. An exothermic reaction is a chemical reaction that releases energy to the surroundings, usually as heat.
2. Cellular respiration is exothermic because the chemical reactions involved release energy from glucose.
3. Some of the energy released during respiration is transferred to ATP, while some is released as heat to the surroundings.
4. The energy released during respiration provides the energy needed for cellular processes, such as active transport, movement, growth and synthesis.
5. An exothermic reaction releases energy to the surroundings, whereas an endothermic reaction takes in energy from the surroundings.
6. Evidence for energy release during respiration includes an increase in temperature, such as when heat produced by respiring organisms is detected.

B1.3c — Compare the processes of aerobic and anaerobic respiration in plants/fungi and animals

1. Aerobic respiration requires oxygen, whereas anaerobic respiration occurs without oxygen.
2. The substrates for aerobic respiration are glucose and oxygen.
3. In animals, anaerobic respiration produces lactic acid. In plants and fungi, anaerobic respiration produces ethanol and carbon dioxide.
4. Aerobic respiration produces the greatest yield of ATP because glucose is broken down more completely in the presence of oxygen.
5.

Type of respiration	Conditions	Substrates	Products	ATP yield
Aerobic	Oxygen present	Glucose + oxygen	Carbon dioxide + water	High

Anaerobic in animals	Oxygen unavailable/insufficient	Glucose	Lactic acid	Low
Anaerobic in plants/fungi	Oxygen unavailable/insufficient	Glucose	Ethanol + carbon dioxide	Low

6. Organisms carry out anaerobic respiration when oxygen is unavailable or insufficient, because it still releases some energy from glucose and produces ATP, although much less than aerobic respiration.

B1.3d — Explain the importance of sugars in the synthesis and breakdown of carbohydrates

1. A monomer is a small molecule that can join with other monomers to form a polymer. A polymer is a large molecule made from many smaller repeating units.
2. Simple sugars such as glucose are the monomers used to build carbohydrates.
3. Carbohydrates are synthesised when sugar molecules are joined together to form larger carbohydrate molecules.
4. Carbohydrates are broken down by breaking the bonds between their sugar units, producing smaller sugars such as glucose.
5. Carbohydrate synthesis allows organisms to store and use energy, while carbohydrate breakdown provides sugars that can be used in processes such as cellular respiration.
6. Carbohydrates are described as polymers because complex carbohydrates can consist of many sugar monomers joined together.

B1.3e — Explain the importance of amino acids in the synthesis and breakdown of proteins

1. In proteins, a monomer is an amino acid and a polymer is a protein made from many amino acids joined together.
2. The monomers that make up proteins are amino acids.
3. Amino acids are joined together by chemical bonds to form long chains called polypeptides, which fold to form proteins.

4. Proteins are broken down by breaking the bonds between amino acids, producing individual amino acids.
5. Amino acids are needed to synthesise proteins required for growth and repair of tissues and cells.
6. Proteins are described as polymers because they are large molecules made from many amino acid monomers joined together.

B1.3f — Explain the importance of fatty acids and glycerol in the synthesis and breakdown of lipids

1. A lipid is formed from fatty acids and glycerol.
2. Fatty acids and glycerol are joined together by chemical reactions to synthesise lipids.
3. Lipids are broken down by breaking the bonds between fatty acids and glycerol, releasing fatty acids and glycerol.
4. Lipids are important as energy stores, provide insulation and form an important component of cell membranes.
5. Carbohydrates are made from sugar units, whereas lipids are made from fatty acids and glycerol. Both can be synthesised into larger molecules and broken down into smaller molecules.
6. Fatty acids and glycerol are essential building blocks of lipids because they combine to form the structure of lipid molecules and are released when lipids are broken down.

B1.4 Photosynthesis

B1.4a — Describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth

1. Photosynthetic organisms are organisms that use light energy to make organic substances, such as glucose, by photosynthesis.
2. Examples of photosynthetic organisms include green plants and algae.
3. Photosynthetic organisms are the main producers of food because they make organic food molecules from carbon dioxide and water using light energy.
4. Biomass is the total mass of living biological material in an organism, population or ecosystem.
5. Most food chains depend on photosynthetic organisms because they produce organic food molecules that provide energy and biomass for other organisms.
6. Life on Earth depends on photosynthetic organisms because they provide food and biomass, and photosynthesis also releases oxygen needed for aerobic respiration.

B1.4b — Describe the process of photosynthesis

1. Carbon dioxide + water → glucose + oxygen.
2. The reactants are carbon dioxide and water. The products are glucose and oxygen.
3. Photosynthesis can be described as a two-stage process because light energy is captured and used to drive reactions that ultimately produce glucose.
4. Photosynthesis takes place in the chloroplasts of photosynthetic cells.
5. Chloroplasts contain chlorophyll, which absorbs light energy needed to drive photosynthesis.
6. Carbon dioxide enters the leaf through the stomata and water is transported to the leaves through the xylem. Chlorophyll absorbs light energy, which is used to convert carbon dioxide and water into glucose, with oxygen released as a by-product.

B1.4c — Describe photosynthesis as an endothermic reaction

1. An endothermic reaction is a chemical reaction that takes in energy from the surroundings.
2. Photosynthesis is endothermic because it requires an input of light energy to convert carbon dioxide and water into glucose and oxygen.
3. The source of energy for photosynthesis is light energy from the Sun.
4. An endothermic reaction takes in energy from the surroundings, whereas an exothermic reaction releases energy to the surroundings.
5. During photosynthesis, light energy is absorbed by chlorophyll and transferred into chemical energy stored in glucose.
6. Evidence that photosynthesis requires an input of energy is that photosynthesis only occurs when a suitable light source is available; plants exposed to light produce starch, whereas areas kept in darkness do not.

B1.4d — Describe experiments to investigate photosynthesis

1. To test a leaf for starch, boil the leaf in water, then heat it in ethanol in a water bath to remove chlorophyll. Rinse it in water and add iodine solution. A blue-black colour indicates starch.
2. Part of a leaf is covered with an opaque material to prevent light reaching that area, allowing it to be compared with an exposed area.
3. A plant is destarched by keeping it in darkness for a sufficient period of time, so that stored starch is used up before the investigation.
4. Iodine solution is used to test for starch; it turns blue-black when starch is present.
5. A blue-black colour shows that starch is present, providing evidence that photosynthesis has occurred.

6. If the exposed part of a leaf turns blue-black but the covered part does not, this shows that excluding light prevents starch formation and therefore demonstrates that light is required for photosynthesis.

B1.4e — Explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis

1. Increasing light intensity generally increases the rate of photosynthesis because more light energy is available, until another factor becomes limiting and the rate levels off.
2. Increasing carbon dioxide concentration generally increases the rate of photosynthesis because carbon dioxide is a reactant, until another factor becomes limiting.
3. As temperature increases, the rate of photosynthesis generally increases because enzyme-controlled reactions occur faster, up to an optimum temperature. Above the optimum, enzymes can become denatured and the rate decreases.
4. Increasing one factor does not always increase the rate because another factor may have become the limiting factor.
5. Reducing light intensity or carbon dioxide concentration will generally decrease the rate of photosynthesis. Reducing temperature below the optimum will also decrease the rate.
6. Change one factor, such as light intensity, while keeping temperature and carbon dioxide concentration constant. Measure the rate of photosynthesis, for example by measuring the volume of oxygen produced in a fixed time, and repeat the experiment at different values of the independent variable.

B1.4f — Explain the interaction of temperature, light intensity and carbon dioxide concentration in limiting the rate of photosynthesis using graphs depicting the effects of the limiting factors

1. A limiting factor is a factor that, when in short supply, limits the rate of a process.
2. Light intensity can become the limiting factor when there is insufficient light energy for photosynthesis. Increasing light intensity then increases the rate until another factor becomes limiting.
3. Carbon dioxide concentration can become the limiting factor when there is insufficient carbon dioxide for photosynthesis. Increasing carbon dioxide concentration then increases the rate until another factor becomes limiting.
4. Temperature can become a limiting factor when it is too low for enzyme-controlled reactions to occur rapidly. Increasing temperature

increases the rate up to an optimum, beyond which the rate decreases because enzymes become denatured.
5. On a graph, increasing the limiting factor initially causes the rate of photosynthesis to increase. The graph then levels off when another factor becomes limiting.
6. Graphs can identify the limiting factor by showing which variable causes the rate of photosynthesis to increase when it is increased. Once increasing that variable no longer increases the rate, another factor is limiting.

B2 Scaling Up

B2.1 Supplying the Cell

B2.1a — Explain how substances are transported into and out of cells through diffusion, osmosis and active transport

1. Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration. Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane. Active transport is the movement of substances against a concentration gradient using energy.
2. During diffusion, particles move down their concentration gradient, from an area of higher concentration to an area of lower concentration, until they become more evenly distributed.
3. During osmosis, water molecules move from a region of higher water potential to lower water potential through a partially permeable membrane.
4. Oxygen can be transported by diffusion, water by osmosis, and mineral ions can be transported by active transport.
5. Diffusion moves particles from high to low concentration, osmosis moves water from high to low water potential, and active transport moves substances from low to high concentration.
6. Active transport requires energy because substances are moved against their concentration gradient, whereas diffusion and osmosis are passive processes that do not require energy from respiration.

B2.1b — Describe the process of mitosis in growth, including the cell cycle

1. Mitosis produces new cells for growth, repair and replacement of damaged or worn-out cells.
2. The cell cycle consists of cell growth, DNA replication, mitosis and cell division.
3. During DNA replication, the DNA molecule is copied so that each chromosome has two identical copies of its genetic information.
4. During mitosis, the chromosomes are separated so that one copy of each chromosome moves to each end of the cell.
5. Mitosis produces two genetically identical daughter cells because the DNA is replicated before mitosis and the replicated chromosomes are evenly separated between the two new cells.
6. Mitosis is important for growth and repair because it produces new genetically identical cells, increasing cell number and replacing damaged or old cells.

B2.1c — Explain the importance of cell differentiation

1. Cell differentiation is the process by which an unspecialised cell develops into a cell with a specialised structure and function.
2. Cell differentiation allows cells to become specialised for particular functions, making the organism more efficient.
3. A specialised cell is a cell that has structures and features adapted to perform a particular function.
4. Red blood cells transport oxygen, nerve cells transmit electrical impulses, and root hair cells absorb water and mineral ions from the soil.
5. Cell differentiation occurs when cells develop different structures and functions due to different genes being expressed, producing specialised cells.
6. Multicellular organisms require many specialised cell types because different cells perform different functions, allowing complex organisms to carry out all the processes needed for survival.

B2.1d — Recall that stem cells are present in embryonic and adult animals, and meristems in plants

1. A stem cell is an unspecialised cell that can divide and produce new cells that can differentiate into specialised cell types.
2. Embryonic stem cells are found in the early embryo.
3. Adult stem cells are found in certain tissues and organs, such as bone marrow.

4. In plants, stem cells are found in meristems, particularly at the tips of roots and shoots.
5. A meristem is a region of actively dividing, unspecialised plant cells that can differentiate into different plant cell types.
6. Embryonic stem cells are found in early embryos, adult stem cells are found in particular tissues such as bone marrow, and plant stem cells are found in meristems.

B2.1e — Describe the functions of stem cells in embryonic and adult animals, and meristems in plants

1. Embryonic stem cells divide and differentiate to produce the different specialised cell types needed to form the developing organism.
2. Adult stem cells produce new cells for growth and repair and replacement of damaged or worn-out cells in particular tissues.
3. Meristems produce new plant cells that can differentiate into different types of specialised plant cells, allowing plants to grow.
4. Stem cells contribute to development, growth and repair by dividing to produce new cells and differentiating into specialised cell types.
5. Stem cells can produce a range of cell types because they are unspecialised cells that can divide and differentiate into specialised cells.
6. Embryonic stem cells contribute to the development of the whole organism, adult stem cells mainly maintain and repair particular tissues, and plant meristems produce cells responsible for plant growth and development.

B2.1f — Describe the difference between embryonic and adult stem cells in animals

1. Embryonic stem cells are found in early embryos and can differentiate into a wide range of specialised cell types. Adult stem cells are found in particular tissues and generally have a more limited ability to differentiate.
2. Embryonic stem cells can differentiate into the greatest variety of cell types.
3. Embryonic stem cells have greater potential because they are less specialised and can differentiate into many different types of cell.
4. Both embryonic and adult stem cells are unspecialised cells that can divide and differentiate into specialised cells.
5. Adult stem cells can be used to produce new blood cells from bone marrow stem cells, helping to replace damaged or diseased blood cells.
6. Embryonic stem cells are particularly important during early development because they can differentiate into many different specialised cell types needed to form the developing organism.

B2 Scaling Up

B2.2 The Challenges of Size

B2.2a — Explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area : volume ratio

1. The surface area : volume ratio compares the total surface area of an organism or object with its total volume.
2. For a cube with sides of 3 cm: surface area = $6 \times 3^2 = 54$ cm^2; volume = $3^3 = 27$ cm^3; surface area : volume ratio = 54 : 27 = 2 : 1.
3. As an organism increases in size, its volume increases faster than its surface area, so its surface area : volume ratio decreases.
4. Large multicellular organisms have a small surface area : volume ratio, so there is not enough surface area for sufficient oxygen and nutrients to enter all cells by diffusion alone.
5. A greater diffusion distance means substances take longer to diffuse, reducing the rate and efficiency of diffusion.
6. Large multicellular organisms require specialised exchange surfaces with a large surface area and short diffusion distances, together with transport systems, because their low surface area : volume ratio makes diffusion alone insufficient to supply all cells.

B2.2b — Describe some of the substances transported into and out of a range of organisms in terms of the requirements of those organisms

1. Four substances transported into or out of organisms are oxygen, carbon dioxide, water and dissolved food molecules.
2. Oxygen is transported into animal cells for use in aerobic respiration, which releases energy and produces ATP.
3. Carbon dioxide is transported out of animal cells because it is a waste product of aerobic respiration and can be harmful if it accumulates.
4. Water must be transported into and around organisms because it is needed for chemical reactions, transport and maintaining cells, and is a raw material for photosynthesis in plants.
5. Dissolved food molecules such as glucose and amino acids are transported to cells so they can be used for respiration, growth, repair and synthesis of biological molecules.
6. Plants transport water and mineral ions into the plant and sugars away from photosynthesising tissues, while animals transport substances such

as oxygen, glucose and amino acids to cells and carry carbon dioxide and urea away as waste products.

B2.2b — Describe some of the substances transported into and out of a range of organisms in terms of the requirements of those organisms

1. Six substances transported into or out of living organisms are oxygen, carbon dioxide, water, dissolved food molecules, mineral ions and urea.
2. Oxygen is transported into animal cells for aerobic respiration, allowing energy to be transferred to ATP.
3. Carbon dioxide is transported out of animal cells because it is a waste product of aerobic respiration.
4. Water and dissolved food molecules must be transported around multicellular organisms because cells require water for chemical reactions and transport, while food molecules provide materials and energy for respiration, growth and repair.
5. Mineral ions are transported into plants because they are needed for healthy growth and the production of substances such as proteins and chlorophyll.
6. Urea is transported out of the body because it is a nitrogen-containing waste product. It is produced in the liver when excess amino acids are broken down.

B2.2c — Describe the human circulatory system

1. The main function of the human circulatory system is to transport substances around the body, including oxygen, nutrients, carbon dioxide and waste products.
2. The circulatory system transports oxygen from the lungs to body cells and carries carbon dioxide from body cells to the lungs for removal.
3. A double circulatory system is a circulatory system in which blood passes through the heart twice during one complete circuit of the body.
4. In the pulmonary circulation, blood travels from the right ventricle to the lungs and back to the left atrium. In the systemic circulation, blood travels from the left ventricle to the body and back to the right atrium.
5. Mammals require a double circulatory system because it allows blood to be pumped to the lungs for oxygenation and then pumped at high pressure to the rest of the body, supporting their high metabolic demands.
6. The circulatory system consists of the heart and blood vessels, including arteries, veins and capillaries, which form a network connecting the heart, lungs and body tissues.

B2.2d — Explain how the structure of the heart and the blood vessels are adapted to their functions

1. The four chambers are the right atrium, right ventricle, left atrium and left ventricle.
2. The main valves are the tricuspid, pulmonary, mitral and aortic valves. Major vessels include the vena cava, pulmonary artery, pulmonary vein and aorta.
3. Cardiac muscle is adapted to contract repeatedly and rhythmically, allowing the heart to pump blood continuously around the body.
4. Arteries have thick muscular and elastic walls and a relatively narrow lumen, with no valves. Veins have thinner walls, a wider lumen and valves. Capillaries have very thin walls, only one cell thick, and a very narrow lumen.
5. Arteries need strong, elastic walls to withstand high pressure. Veins need valves to prevent backflow because blood pressure is lower. Capillaries have thin walls to provide a short diffusion distance for exchange of substances.
6. The heart provides pressure to move blood around the body, while the specialised structures of arteries, veins and capillaries allow blood to be transported efficiently and substances exchanged with tissues.

B2.2e — Explain how red blood cells and plasma are adapted to their transport functions in the blood

1. Red blood cells contain haemoglobin, which binds to oxygen. They have a biconcave shape and no nucleus, allowing efficient oxygen transport.
2. Their biconcave shape provides a large surface area and short diffusion distance, allowing oxygen to diffuse into and out of the cell efficiently.
3. Mature red blood cells have no nucleus, providing more space for haemoglobin and therefore increasing their oxygen-carrying capacity.
4. Plasma is the liquid component of blood that transports dissolved substances around the body.
5. Plasma transports substances including carbon dioxide, urea, glucose and amino acids. It also transports hormones and mineral ions.
6. Red blood cells efficiently transport oxygen using haemoglobin, while plasma transports dissolved substances throughout the body, allowing materials and waste products to move efficiently between organs and tissues.

B2.2f — Explain how water and mineral ions are taken up by plants, relating the structure of the root hair cells to their function

1. Water enters root hair cells by osmosis, moving from an area of higher water potential in the soil to lower water potential in the root hair cell through the partially permeable cell membrane.
2. Mineral ions enter root hair cells by active transport, moving from a lower concentration in the soil to a higher concentration inside the root hair cells using energy from respiration.
3. Root hair cells have a large surface area, a long extension providing a short diffusion distance, and many mitochondria to provide energy for active transport.
4. Root hair cells have a large surface area, which provides more membrane through which water and mineral ions can be absorbed.
5. Water enters root hair cells by osmosis down a water potential gradient without requiring energy, whereas mineral ions can enter by active transport against a concentration gradient using energy.
6. The long extensions and large surface area of root hair cells increase absorption, while their mitochondria provide energy for active transport of mineral ions, allowing plants to obtain the water and minerals needed for growth.

B2.2g — Describe the processes of transpiration and translocation

1. Transpiration is the loss of water vapour from a plant, mainly through the stomata in the leaves.
2. Translocation is the transport of dissolved sugars, particularly sucrose, through the phloem from sources to sinks.
3. Stomata allow gas exchange and provide a route through which water vapour is lost from the leaves during transpiration.
4. The xylem transports water and dissolved mineral ions from the roots to the rest of the plant.
5. The phloem transports dissolved sugars, such as sucrose, around the plant.
6. Transpiration is the loss of water vapour from leaves and is associated with the movement of water through the xylem, whereas translocation is the movement of dissolved sugars through the phloem.

B2.2h — Explain how the structure of the xylem and phloem are adapted to their functions in the plant

1. The xylem transports water and dissolved mineral ions from the roots to the rest of the plant.
2. The phloem transports dissolved sugars, such as sucrose, around the plant.

3. Xylem vessels are long, continuous hollow tubes with no end walls and have thick, lignified walls, providing strength and preventing collapse under tension.
4. Phloem contains sieve tube elements with sieve plates that allow dissolved sugars to pass through. They are associated with companion cells, which provide the energy needed for transport.
5. Xylem transports water and dissolved mineral ions, whereas phloem transports dissolved sugars, such as sucrose.
6. The hollow, strengthened structure of xylem vessels allows efficient movement of water, while the sieve tubes and companion cells of the phloem allow dissolved sugars to be transported throughout the plant.

B2.2i — Explain the effect of a variety of environmental factors on the rate of water uptake by a plant

1. Increasing light intensity increases the rate of transpiration by causing stomata to open, increasing water loss from the leaves and therefore increasing water uptake from the roots.
2. Increasing temperature increases the rate of evaporation and diffusion of water vapour from leaves, increasing transpiration and therefore water uptake.
3. Increasing air movement removes water vapour from around the leaf, maintaining a steep water vapour concentration gradient and increasing transpiration and water uptake.
4. The rate increases from 2.4 cm^3/hour to 4.8 cm^3/hour. 4.8 ÷ 2.4 = 2, so the rate has increased by a factor of 2.
5. Increase = 3.6 − 1.5 = 2.1 cm^3/hour.
6. The rate of water uptake would decrease because low light reduces stomatal opening, low temperature reduces evaporation, and still air reduces the movement of water vapour away from the leaf.

B2.2j — Describe how a simple potometer can be used to investigate factors that affect the rate of water uptake

1. A potometer is used to estimate the rate of water uptake by a plant shoot.
2. A leafy shoot is fitted into an airtight potometer containing water. A bubble is introduced into the capillary tube and the distance moved by the bubble is measured over a fixed time. The experiment is repeated at different light intensities while other factors are controlled.
3. Only one variable should be changed so that any change in the rate of water uptake can be attributed to the independent variable being investigated.
4. Rate = distance ÷ time = 36 ÷ 9 = 4 mm/min.
5. Mass lost = 18.0 − 16.2 = 1.8 g. Percentage loss = (1.8 ÷ 18.0) × 100 = 10%.

6. At 20°C: 18 ÷ 6 = 3 mm/min. At 30°C: 42 ÷ 6 = 7 mm/min. Therefore, 30°C produced the greater rate of water uptake.

B3 Organism Level Systems

B3.1 Coordination and Control – The Nervous System

B3.1a — Describe the structure of the nervous system

1. The central nervous system (CNS) consists of the brain and spinal cord and processes information and coordinates the body's responses.
2. The brain receives and processes information and coordinates responses to stimuli.
3. The spinal cord carries nerve impulses between the brain and the rest of the nervous system and coordinates reflex responses.
4. A sensory neurone carries electrical impulses from sensory receptors to the CNS.
5. A relay neurone carries electrical impulses between sensory and motor neurones within the CNS.
6. A motor neurone carries electrical impulses from the CNS to effectors, such as muscles or glands.

B3.1b — Explain how the components of the nervous system can produce a coordinated response

1. A stimulus is a change in the environment that can be detected by an organism.
2. A receptor is a specialised cell or group of cells that detects a stimulus and produces a response in the form of a nerve impulse.
3. An effector is a muscle or gland that produces a response to a nerve impulse.
4. Receptors detect changes in the environment and generate electrical impulses in sensory neurones, which carry information to the CNS for processing.
5. Effectors carry out the response coordinated by the nervous system. Muscles contract and glands secrete substances in response to nerve impulses.
6. The sharp drawing pin stimulates pain receptors in the foot. A sensory neurone carries impulses to the CNS, where a relay neurone passes the

impulse to a motor neurone. The motor neurone carries the impulse to the leg muscles, causing them to contract and withdraw the foot.

B3.1c — Explain how the structure of a reflex arc is related to its function

1. A reflex action is a rapid, automatic response to a stimulus that does not require conscious thought.
2. The correct order is receptor → sensory neurone → relay neurone → motor neurone → effector.
3. Reflex actions are usually faster because the response is coordinated through the spinal cord rather than requiring conscious processing by the brain, reducing the distance and time involved.
4. Touching a hot pan causes heat receptors in the skin to detect the stimulus and initiate a rapid nerve pathway through the spinal cord, causing the arm muscles to contract and remove the hand without conscious thought.
5. A relay neurone connects the sensory neurone to the motor neurone within the CNS, allowing the nerve impulse to pass rapidly from the receptor to the effector.
6. The reflex response is 0.33 s faster than the voluntary response. Calculation: 0.48 − 0.15 = 0.33 s.

B3 Organism Level Systems

B3.2 Coordination and Control – The Endocrine System

B3.2a — Describe the principles of hormonal coordination and control by the human endocrine system

1. A hormone is a chemical messenger produced by an endocrine gland and transported in the blood to a target organ or tissue.
2. Hormones are described as chemical messengers because they carry information between different parts of the body and cause specific responses in target cells.
3. Hormones are produced by endocrine glands.
4. Hormones are transported around the body in the bloodstream.

5. A receptor is a protein on or inside a target cell that specifically binds to a particular hormone.
6. A hormone affects only particular target cells or organs because only cells with the specific receptor for that hormone can respond to it.

B3.2b — Explain the roles of thyroxine and adrenaline in the body

1. Thyroxine is produced by the thyroid gland.
2. Thyroxine helps control the body's metabolic rate, increasing the rate at which chemical reactions occur.
3. Thyroxine release is controlled by negative feedback. When thyroxine levels become too high, the signals stimulating its production are reduced, lowering thyroxine production. When levels fall, stimulation increases.
4. Adrenaline is produced by the adrenal glands.
5. Adrenaline increases heart rate and breathing rate, increases blood flow to muscles, and increases blood glucose concentration, preparing the body for rapid action.
6. These effects increase survival chances by providing more oxygen and glucose to muscles, allowing the body to respond quickly to a dangerous situation.

B3.2c — Describe the role of hormones in human reproduction including the control of the menstrual cycle

1. FSH (follicle stimulating hormone) stimulates the development and maturation of an ovarian follicle containing an egg.
2. Oestrogen is produced by the developing follicle and helps rebuild the lining of the uterus. It also inhibits FSH release and, at high levels, stimulates the release of LH.
3. Progesterone maintains the lining of the uterus after ovulation and inhibits the release of FSH and LH.
4. Testosterone is produced by the testes and stimulates sperm production and the development of male secondary sexual characteristics.
5. Oestrogen causes the uterus lining to thicken after menstruation, while progesterone maintains the thickened lining after ovulation so it is suitable for implantation.
6. Hormones control the menstrual cycle by changing the levels of FSH, oestrogen, LH and progesterone, which regulate follicle development, ovulation and maintenance of the uterus lining.

B3.2d — Explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle

1. LH (luteinising hormone) causes ovulation, the release of a mature egg from the ovary.
2. FSH stimulates the development of an ovarian follicle, which produces oestrogen. Rising oestrogen levels cause FSH release to decrease, while high oestrogen levels stimulate the release of LH.
3. Oestrogen initially inhibits FSH release, reducing the development of additional follicles. When oestrogen reaches a high level, it causes a surge in LH, leading to ovulation.
4. Progesterone inhibits the release of FSH and LH, preventing another follicle from developing and another ovulation from occurring during the same menstrual cycle.
5. FSH stimulates follicle development, the follicle produces increasing levels of oestrogen, high oestrogen levels trigger an LH surge, and the LH surge causes ovulation.
6. FSH stimulates follicle development, the follicle produces oestrogen, high oestrogen stimulates LH release, and LH causes ovulation. After ovulation, progesterone is produced and maintains the uterus lining while inhibiting FSH and LH.

B3.2e — Explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception

1. One hormonal method of contraception is the combined oral contraceptive pill, which contains oestrogen and progesterone-like hormones.
2. One non-hormonal method of contraception is a condom.
3. Hormonal contraception can prevent pregnancy by inhibiting FSH and LH, preventing ovulation. It can also thicken cervical mucus, making it more difficult for sperm to reach an egg.
4. A condom prevents pregnancy by acting as a physical barrier, preventing sperm from entering the female reproductive system.
5. Hormonal methods can be highly effective when used correctly, while the effectiveness of non-hormonal methods varies. Barrier methods can also provide protection against sexually transmitted infections, which hormonal methods do not.
6. Hormonal contraception is generally effective and reversible but can cause side effects and requires correct use. Non-hormonal methods avoid hormone-related side effects, and condoms can protect against sexually transmitted infections, but some non-hormonal methods are less effective with typical use.

B3.2f — Explain the use of hormones in modern reproductive technologies to treat infertility

1. Infertility is the inability to become pregnant after a prolonged period of regular unprotected sexual intercourse.
2. Hormones such as FSH can be administered to stimulate the development and maturation of eggs in the ovaries.
3. Hormone treatment can stimulate the maturation and release of eggs, increasing the number of eggs available for fertilisation and therefore increasing the chance of pregnancy.
4. One modern reproductive technology used to treat infertility is IVF (in vitro fertilisation).
5. Hormones can be used to stimulate the ovaries to produce several mature eggs, which can then be collected and fertilised during IVF. Other hormones may then support the uterus lining.
6. Hormone treatments can be effective because they can stimulate egg development and ovulation, correcting or overcoming problems with normal reproductive hormone levels and increasing the opportunity for fertilisation.

B3.3 Maintaining Internal Environments

B3.3a — Explain the importance of maintaining a constant internal environment in response to internal and external change

1. Homeostasis is the maintenance of a constant internal environment in response to internal and external changes.
2. Living organisms need to maintain a constant internal environment so that cells and enzymes can function effectively.
3. Two examples of internal conditions controlled by homeostasis are blood glucose concentration and body temperature.
4. Changes in the external environment, such as changes in temperature, can affect internal conditions, so homeostatic mechanisms act to keep internal conditions within suitable limits.
5. Enzymes and other metabolic reactions require a constant internal environment because changes in conditions such as temperature and pH can alter enzyme activity and affect the rate of metabolic reactions.
6. Maintaining homeostasis is essential for survival because cells depend on stable internal conditions for normal enzyme activity, metabolism and other vital processes.

B3.3b — Explain how insulin controls blood sugar levels in the body

1. Insulin is produced by the pancreas.
2. Insulin is released into the bloodstream when blood glucose concentration becomes too high.

3. Insulin lowers blood glucose concentration by causing cells to take up more glucose and by stimulating the liver to convert glucose into glycogen for storage.
4. Excess glucose is converted into glycogen and stored mainly in the liver and muscles.
5. Blood glucose concentration must be kept within a narrow range because cells require a constant supply of glucose for respiration, while excessively high or low concentrations can damage normal body function.
6. Insulin helps maintain homeostasis by reducing high blood glucose concentrations, returning them towards the normal level.

B3.3c — Explain how glucagon interacts with insulin to control blood sugar levels in the body

1. Glucagon is released when blood glucose concentration falls too low.
2. Glucagon is produced by the pancreas.
3. Glucagon increases blood glucose concentration by causing the liver to convert stored glycogen into glucose, which is then released into the blood.
4. Insulin decreases blood glucose concentration, whereas glucagon increases blood glucose concentration.
5. When blood glucose is too high, insulin lowers it by promoting glucose uptake and glycogen formation. When blood glucose is too low, glucagon raises it by promoting glycogen breakdown and glucose release. Together they maintain blood glucose within a suitable range.
6. The interaction is an example of homeostasis because insulin and glucagon counteract changes in blood glucose concentration, maintaining a relatively constant internal condition.

B3.3d — Compare type 1 and type 2 diabetes and explain how they can be treated

1. Type 1 diabetes occurs when the pancreas produces little or no insulin because the insulin-producing cells are destroyed by the body's immune system.
2. Type 2 diabetes occurs when body cells become less responsive to insulin, often associated with factors such as being overweight and having a sedentary lifestyle.
3. Type 1 diabetes involves a lack of insulin production and usually requires insulin treatment. Type 2 diabetes involves insulin resistance and can often initially be managed through lifestyle changes and medication.
4. A main treatment for type 1 diabetes is regular injections or administration of insulin.

5. Two treatments for type 2 diabetes are a controlled diet and increased physical activity. Medication may also be used.
6. Type 1 diabetes requires insulin because the body produces little or no insulin, whereas type 2 diabetes may be managed initially by lifestyle changes and medicines that improve blood glucose control because the body still produces some insulin.

Paper 2:

Topic B4: Community level systems

B4.1 Ecosystems

B4.1a — Recall that many different materials cycle through the abiotic and biotic components of an ecosystem

1. Abiotic components are the non-living parts of an ecosystem, such as air, water, soil, temperature and light. Biotic components are the living parts of an ecosystem, including plants, animals and microorganisms.
2. Materials cycle through an ecosystem by moving between the non-living environment and living organisms before eventually being returned to the environment and reused.
3. When materials move from abiotic components into living organisms, they are absorbed or taken in and used to build substances needed for growth and other life processes.
4. Materials move from biotic components back into the abiotic environment through processes such as respiration, excretion and decomposition.
5. Two examples of materials that cycle through ecosystems are carbon and nitrogen.
6. Carbon and nitrogen must be continually recycled because there is a limited supply of these materials in ecosystems and living organisms continually need them to build important biological molecules.

B4.1b — Explain the role of microorganisms in the cycling of materials through an ecosystem

1. Microorganisms act as decomposers, breaking down dead organisms and waste materials and returning substances to the environment so they can be reused by other organisms.

2. Decomposition is the breakdown of dead organic material and waste. Microorganisms decompose materials such as dead plants, dead animals, faeces and other organic waste.
3. Microorganisms such as bacteria and fungi act as decomposers by feeding on and breaking down organic material using enzymes.
4. During decomposition, microorganisms break down complex substances in dead organisms and waste into simpler substances. These materials are released back into the soil, water or atmosphere where they can be reused.
5. Different ecosystems could be sampled and observations made of decaying material. Samples could be collected and examined to identify microorganisms such as bacteria and fungi associated with decomposition.
6. Decomposer microorganisms are essential because they return materials from dead organisms and waste to the environment. Without decomposition, nutrients would remain locked within dead material and would not be available for reuse by other organisms.

B4.1c — Explain the importance of the carbon cycle and the water cycle to living organisms

1. The carbon cycle is important because carbon is required to make biological molecules such as carbohydrates, proteins and fats that are needed by living organisms.
2. Carbon dioxide is removed from the atmosphere by plants during photosynthesis and incorporated into organic molecules. Carbon is transferred between organisms through feeding and returned to the atmosphere by respiration, decomposition and combustion.
3. The water cycle is important because all living organisms require water for processes such as chemical reactions, transport of substances and maintaining cells.
4. The main stages of the water cycle include evaporation, condensation, precipitation and the return of water to rivers, lakes and oceans through surface runoff and groundwater.
5. The water cycle continually supplies freshwater to habitats through precipitation, while the carbon cycle provides carbon needed by producers and other organisms, helping maintain functioning ecosystems.
6. The carbon and water cycles continually move essential materials between organisms and the environment, making them available for uptake and use by living organisms throughout ecosystems.

B4.1d — Describe different levels of organisation in an ecosystem from individual organisms to the whole ecosystem

1. An individual organism is one single living organism, such as one rabbit, one oak tree or one bacterium.
2. A population is all the organisms of one species living in a particular area. It differs from an individual organism because it contains many organisms of the same species rather than just one.
3. A community consists of all the populations of different species living and interacting in a particular area, whereas a population contains organisms of only one species.
4. An ecosystem consists of a community of living organisms interacting with each other and with the non-living, abiotic components of their environment.
5. The correct order of organisation is individual organism → population → community → ecosystem.
6. The number and variety of organisms generally increases from an individual organism to a population, then to a community and finally to an ecosystem, which contains many populations of different species.

B4.1e — Explain how abiotic and biotic factors can affect communities

1. Temperature can affect enzyme activity, growth and survival, while light intensity affects the rate of photosynthesis in plants. These factors therefore influence which organisms can survive and reproduce in a community.
2. Moisture level affects the availability of water to organisms, while soil pH affects the availability of mineral ions and the conditions in which plants and microorganisms can survive. This affects their distribution and abundance.
3. Predators can reduce the size of prey populations by consuming them. Changes in predator numbers can therefore affect both the abundance and distribution of prey populations.
4. If more food is available, a population may be able to support more individuals and increase in size. If food becomes limited, competition increases and the population may decrease.
5. Sampling techniques such as quadrats and transects can be used to measure the abundance and distribution of organisms, allowing relationships between different organisms and other biotic factors to be investigated.
6. The abundance and distribution of organisms could be measured at different values of an environmental factor. For example, quadrats could be placed along a transect and the number of organisms recorded alongside measurements of an abiotic factor such as light intensity or soil moisture.

B4.1f — Describe the importance of interdependence and competition in a community

1. Interdependence means that organisms within a community depend on other organisms for resources and survival, such as food, shelter, pollination or reproduction.
2. Predation demonstrates interdependence because predators depend on prey as a source of food, while changes in predator populations can also affect the size of prey populations.
3. Mutualism is a relationship between two different species in which both organisms benefit. For example, insects obtain food from flowers while helping the plants reproduce through pollination.
4. Parasitism is a relationship in which one organism, the parasite, benefits while the host is harmed. The parasite depends on the host for resources such as food or shelter.
5. Interdependence is important because organisms rely on one another for resources and processes necessary for survival and reproduction. A change in one population can therefore affect other populations within the community.
6. Organisms compete because resources are limited. Animals may compete for food, water, territory and mates, while plants may compete for light, water, space and mineral ions.

B5 Genes, Inheritance and Selection

B5.1 Inheritance

B5.1a — explain the following terms: gamete, chromosome, gene, allele/variant, dominant, recessive, homozygous, heterozygous, genotype and phenotype

1. A gamete is a sex cell, such as a sperm or egg cell, containing a haploid set of chromosomes, so it has half the chromosome number of a body cell.
2. A chromosome is a long DNA molecule containing many genes. A gene is a section of DNA that codes for a particular protein or characteristic, while an allele/variant is a different version of a gene.

3. A dominant allele is expressed in the phenotype when present in either a homozygous or heterozygous genotype. A recessive allele is only expressed when two copies are present.
4. A homozygous genotype contains two identical alleles for a gene, whereas a heterozygous genotype contains two different alleles.
5. An organism's genotype is the combination of alleles it possesses, whereas its phenotype is the observable characteristics resulting from its genotype and environmental influences.
6. The alleles inherited from the parents determine the organism's genotype, which can be used to predict the phenotype, particularly when the alleles have known dominant and recessive relationships.

B5.1b — describe the genome as the entire genetic material of an organism

1. The genome is the entire genetic material of an organism.
2. An organism's genome consists of all of its DNA, including all of its genes and other DNA sequences.
3. The genome is contained within the organism's complete set of chromosomes.
4. A genome contains all of an organism's genetic material, whereas an individual gene is only a specific section of DNA.
5. The genome can be described as the entire genetic material because it contains all the DNA sequences inherited by an organism.
6. An organism's genome contains the genetic information that contributes to its characteristics and biological functions, although phenotype is also influenced by the environment.

B5.1c — describe that the genome, and its interaction with the environment, influence the development of the phenotype of an organism

1. The genome contains genes that provide instructions for proteins and therefore influences the characteristics that develop in an organism.
2. Environmental factors such as diet, temperature, light and exercise can influence an organism's phenotype.
3. Phenotype results from the interaction between genetic factors and environmental factors, so organisms with similar genomes can develop different characteristics in different environments.
4. Discontinuous variation produces distinct categories with no intermediate values, such as blood group.
5. Continuous variation produces a range of values, such as height and body mass.

6. Discontinuous variation has distinct categories, often determined mainly by genetic factors, whereas continuous variation has a range of values and is usually influenced by multiple genes and environmental factors.

B5.1d — recall that all variants arise from mutations, and that most have no effect on the phenotype, some influence phenotype and a very few determine phenotype

1. A mutation is a change in the DNA base sequence that can create a new genetic variant or allele.
2. Most genetic variants have no observable effect on the phenotype.
3. Some genetic variants can influence the phenotype by changing the protein produced or how much of a protein is produced.
4. If a genetic variant determines the phenotype, the characteristic is directly determined by that particular genetic variant, with little or no influence from other genetic or environmental factors.
5. Most mutations have no effect because they may occur in DNA that does not affect protein production, or the change may not alter the function of the resulting protein.
6. A mutation can have no effect on the phenotype, influence the phenotype, or, very rarely, determine the phenotype.

B5.1e — explain the terms haploid and diploid

1. Haploid means having one set of chromosomes.
2. Diploid means having two sets of chromosomes, with one set inherited from each parent.
3. A haploid cell has half the chromosome number of a diploid cell.
4. In humans, sperm and egg cells are haploid.
5. Most human body cells are diploid.
6. Gametes must be haploid so that when two gametes fuse during fertilisation, the normal diploid chromosome number is restored rather than doubled in every generation.

B5.1f — explain the role of meiotic cell division in halving the chromosome number to form gametes

1. Meiosis produces haploid gametes from diploid cells by reducing the chromosome number by half.
2. During meiosis, chromosomes are replicated and then separated through two successive cell divisions, producing cells with half the original chromosome number.
3. Meiosis must produce haploid gametes so that fertilisation does not double the chromosome number in each generation.

4. Two haploid gametes fuse during fertilisation, combining their chromosome sets and restoring the diploid chromosome number.
5. Meiosis produces genetic variation through processes including the random distribution of chromosomes into gametes and the production of genetically different gametes.
6. Meiosis produces haploid gametes, so when two gametes fuse during fertilisation, the resulting offspring is diploid, maintaining the chromosome number between generations.

B5.1g — explain single gene inheritance in the context of homozygous and heterozygous crosses involving dominant and recessive genes

1. Single gene inheritance is the inheritance of a characteristic controlled by a single gene with different alleles.
2. A homozygous dominant genotype has two dominant alleles, a homozygous recessive genotype has two recessive alleles, and a heterozygous genotype has one dominant and one recessive allele.
3. In a heterozygous organism, the dominant allele is expressed in the phenotype.
4. In a heterozygous organism, the recessive allele is not expressed in the phenotype because its effect is masked by the dominant allele.
5. The probability of a particular phenotype can be predicted by using a genetic cross or Punnett square to determine the possible offspring genotypes and their expected ratios.
6. A coin toss or die roll can model genetic probability by representing the random inheritance of alleles. Repeated trials can be used to compare experimental results with expected probabilities.

B5.1h — predict the results of single gene crosses

1. A Punnett square is used to predict the possible genotypes and phenotypes of offspring from a genetic cross.
2. The possible gametes from each parent are written along the top and side of the Punnett square.
3. Combining the allele from each parent in each box gives the possible offspring genotypes.
4. The phenotypes are determined by applying the dominant and recessive relationships to the predicted genotypes.
5. The probability of a particular phenotype is calculated by counting the relevant boxes and dividing by the total number of boxes, then expressing the result as a fraction, decimal or percentage.
6. For a cross between two heterozygous organisms, Aa × Aa, the predicted genotypes are AA, Aa, Aa and aa, giving a genotype ratio of 1 AA : 2 Aa : 1 aa

and, where A is completely dominant, a phenotype ratio of 3 dominant : 1 recessive.

B5.1i — describe sex determination in humans using a genetic cross

1. A human female normally has two X chromosomes (XX).
2. A human male normally has one X chromosome and one Y chromosome (XY).
3. A human egg normally contains an X chromosome.
4. Human sperm can contain either an X chromosome or a Y chromosome.
5. If an X-bearing sperm fertilises an egg, the embryo is XX. If a Y-bearing sperm fertilises an egg, the embryo is XY.
6. A cross between XX and XY gives XX, XY, XX and XY, so the predicted probability is 50% XX and 50% XY.

B5.1j — recall that most phenotypic features are the result of multiple genes rather than single gene inheritance

1. Multiple gene inheritance occurs when a characteristic is influenced by two or more genes.
2. Most phenotypic features are determined by multiple genes because characteristics are often complex and involve the combined effects of many genes.
3. Multiple genes can contribute to continuous variation because different combinations of alleles can produce many possible phenotypes across a range.
4. Characteristics such as height and weight can show a wide range because they are influenced by multiple genes as well as environmental factors.
5. Single gene inheritance involves a characteristic mainly controlled by one gene, whereas multiple gene inheritance involves several genes contributing to a characteristic.
6. Considering multiple genes is important because most phenotypic features are not controlled by a single gene and their expression can also be affected by environmental factors.

B5 Genes, Inheritance and Selection

B5.2 Natural selection and evolution

B5.2a — state that there is usually extensive genetic variation within a population of a species

1. Genetic variation is the differences in alleles and inherited characteristics between individuals within a population.
2. Genetic variation is caused by differences in an individual's genes and alleles, whereas environmental variation is caused by differences in the conditions or experiences individuals are exposed to.
3. Individuals of the same species can have different alleles because mutations create new variants, which can be inherited.
4. Different alleles can produce different characteristics by causing differences in the proteins produced or their function.
5. Genetic variation is necessary for natural selection because it provides differences in characteristics on which selection can act.
6. Greater genetic variation increases the likelihood that some individuals possess inherited characteristics that help them survive environmental changes, allowing the population to adapt.

B5.2b — describe the impact of developments in biology on classification systems

1. A classification system is used to organise organisms into groups based on their similarities and differences and to show relationships between them.
2. A natural classification system groups organisms according to their evolutionary relationships and shared characteristics.
3. An artificial classification system groups organisms using selected observable characteristics that may not reflect their evolutionary relationships.
4. Natural classification aims to reflect evolutionary relationships, whereas artificial classification groups organisms according to chosen observable features.
5. Molecular phylogenetics is the study of evolutionary relationships between organisms using molecular evidence, such as similarities and differences in DNA or protein sequences.
6. DNA sequencing allows scientists to compare genetic information directly, helping them identify evolutionary relationships and revise classifications when genetic evidence shows that organisms are more or less closely related than previously thought.

B5.2c — explain how evolution occurs through the natural selection of variants that have given rise to phenotypes best suited to their environment

1. A mutation is a change in the DNA base sequence that can produce a new genetic variant.
2. Mutations alter DNA and can therefore create new alleles or genetic variants.
3. Different genetic variants can affect the proteins produced by an organism, resulting in differences in phenotype.
4. Organisms with phenotypes that are better suited to their environment are more likely to survive and reproduce successfully.
5. Individuals with advantageous variants are more likely to reproduce and pass these variants to their offspring, so the frequency of advantageous variants increases in the population over generations.
6. Natural selection causes advantageous inherited variants to become more common over successive generations, resulting in a change in the inherited characteristics of the population, which is evolution.

B5.2d — describe evolution as a change in the inherited characteristics of a population over time, through a process of natural selection, which may result in the formation of new species

1. Evolution is a change in the inherited characteristics of a population over time.
2. The frequency of different inherited characteristics and genetic variants changes within a population during evolution.
3. Natural selection favours individuals with advantageous inherited characteristics, causing these characteristics to become more common in the population over successive generations.
4. Individuals with advantageous inherited characteristics are more likely to survive, reproduce and pass their alleles to their offspring, increasing their frequency in later generations.
5. If populations become genetically and reproductively isolated and accumulate enough differences over many generations, they may become unable to interbreed successfully and produce fertile offspring, resulting in new species.
6. The formation of a new species, or speciation, occurs when populations become sufficiently different through evolutionary change that they can no longer successfully interbreed to produce fertile offspring.

B5.2e — describe the evidence for evolution

1. A fossil is the preserved remains, impressions or other evidence of an organism that lived in the past.
2. Fossils provide evidence that organisms have changed over time because fossils from different geological periods show different forms and characteristics, including transitional forms.

3. Differences between fossils from different geological periods can show that species have changed, appeared and become extinct over time.
4. Antibiotic resistance in bacteria provides evidence for evolution because bacterial populations can change over generations as resistant variants are naturally selected.
5. Antibiotics kill susceptible bacteria, while resistant bacteria survive and reproduce. The resistant bacteria therefore become more common in the population.
6. The evolution of antibiotic resistance demonstrates that inherited characteristics can change in frequency over successive generations through natural selection.

B6 Global Challenges

B6.1 Monitoring and maintaining the environment

B6.1a — explain how to carry out a field investigation into the distribution and abundance of organisms in a habitat and how to determine their numbers in a given area

1. Distribution describes where organisms are found within a particular habitat.
2. Abundance describes the number of organisms of a particular species present in a given area.
3. Random sampling using quadrats involves placing quadrats at randomly selected locations and counting or estimating the organisms present. Repeating this allows the distribution and abundance of organisms to be determined.
4. A transect is a line or belt across a habitat along which organisms are sampled at regular intervals to investigate how their distribution changes across the habitat.
5. Pooters and nets can be used to collect organisms safely for sampling, while identification keys can be used to identify the organisms collected.
6. Scaling up uses results from a representative sample to estimate the total number of organisms in a larger area. Capture-recapture involves capturing, marking and releasing organisms, then recapturing a sample to estimate the population size.

B6.1b — describe both positive and negative human interactions within ecosystems and explain their impact on biodiversity

1. Biodiversity is the variety of different species of organisms in a particular habitat, ecosystem or on Earth.
2. Two positive human interactions are conservation of habitats and protection or reintroduction of endangered species.
3. Two negative human interactions are deforestation and hunting, which can reduce populations and destroy habitats.
4. Changes in land use, such as deforestation and urbanisation, can destroy or fragment habitats, reducing populations and causing species to become endangered or extinct.
5. Hunting can reduce the population size of species and, if excessive, can cause species to become endangered or extinct, reducing biodiversity.
6. Conserving individual species and selected habitats can protect endangered populations, preserve habitats and prevent extinctions, helping to maintain biodiversity.

B6.1c — explain some of the benefits and challenges of maintaining local and global biodiversity

1. Two benefits of maintaining biodiversity are maintaining stable ecosystems and providing resources such as food, medicines and raw materials.
2. Biodiversity is important because different species are interdependent, and greater biodiversity can make ecosystems more resilient to environmental changes.
3. It can be difficult to gain agreements for conservation schemes because conservation can conflict with economic interests, local people's needs and the use of land or natural resources.
4. Monitoring conservation schemes is important to determine whether they are successfully protecting or increasing biodiversity and to identify changes that require further action.
5. Ecotourism is tourism that aims to minimise environmental damage while supporting the conservation of natural environments and local communities.
6. Ecotourism can provide income for local communities and funding for conservation, creating an economic incentive to protect habitats and biodiversity.

B6.2 Feeding the human race

B6.2a — explain the impact of the selective breeding of food plants and domesticated animals

1. Selective breeding is the process of choosing parents with desirable characteristics and breeding them together so that their offspring are more likely to inherit those characteristics.
2. Selective breeding in food plants involves choosing plants with desirable characteristics, breeding them, selecting offspring with the best characteristics and repeating the process over many generations.
3. Selective breeding in domesticated animals involves choosing animals with desirable characteristics as parents, breeding them and selecting offspring with the desired characteristics for further breeding.
4. Desirable characteristics in food plants can include high yield, disease resistance, larger fruits or seeds, improved nutritional value and tolerance to environmental conditions.
5. Desirable characteristics in domesticated animals can include high milk or meat production, rapid growth, disease resistance and increased fertility.
6. Selective breeding increases the frequency of alleles associated with desirable characteristics, causing the characteristics of food plants and domesticated animals to change over successive generations.

B6.2b — describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics

1. Genetic engineering is the process of modifying an organism's genetic material to introduce a desired characteristic.
2. The organism's genome, specifically its DNA, is modified during genetic engineering.
3. Genetic engineering introduces a desirable characteristic by inserting a gene responsible for the characteristic into the organism's genome, allowing the organism to produce the relevant protein.
4. A desirable characteristic is a feature considered useful or beneficial, such as pest resistance, disease resistance or increased crop yield.
5. Selective breeding involves choosing organisms with desirable characteristics and breeding them over generations, whereas genetic engineering directly modifies DNA by introducing a specific gene.
6. Genetic engineering can introduce genes from different species, allowing characteristics that would not be available through normal breeding between closely related organisms to be introduced.

B6.2c — describe the main steps in the process of genetic engineering

1. Restriction enzymes cut DNA at specific base sequences, allowing the desired gene to be removed and the vector DNA to be cut.

2. Sticky ends are short, unpaired sections of DNA produced when restriction enzymes make staggered cuts in DNA. They can pair with complementary bases on another DNA fragment.
3. Ligase joins the DNA fragments together by forming bonds in the DNA backbone, joining the desired gene to the vector.
4. A vector is a carrier used to transfer a gene into a host cell. Plasmids are small circular DNA molecules found in bacteria and can be used as vectors because they can carry inserted genes into bacterial cells.
5. The desired gene and plasmid are cut using the same restriction enzyme so they have complementary sticky ends. The gene is joined to the plasmid using DNA ligase, and the genetically engineered plasmid is transferred into a host bacterium.
6. The plasmid contains an antibiotic resistance marker. Bacteria are grown in the presence of the corresponding antibiotic, so bacteria that have taken up the plasmid survive while bacteria without the plasmid are killed.

B6.2d — explain some of the possible benefits and risks of using gene technology in modern agriculture

1. Two potential benefits are increased crop yields and increased resistance to pests or diseases.
2. Genetic engineering can increase crop yields by introducing genes that improve characteristics such as growth rate, disease resistance or tolerance to environmental conditions, reducing crop losses.
3. Genetic engineering can introduce genes that make crops resistant to pests or diseases, reducing damage to crops and potentially reducing the need for pesticides.
4. Two potential risks are the spread of modified genes to wild populations and the possibility of unintended effects on ecosystems or non-target organisms.
5. Practical considerations include the cost of developing and producing GM organisms, effectiveness, effects on surrounding ecosystems, potential spread of genes and long-term monitoring.
6. Ethical considerations include whether it is acceptable to modify organisms genetically, potential effects on animal welfare, ownership and control of genetically modified crops, and concerns about impacts on natural ecosystems.

B6 Global Challenges

B6.3 Monitoring and maintaining health

B6.3a — describe the relationship between health and disease

1. Health is a state of physical and mental well-being.
2. Disease is a condition that affects the normal functioning of an organism.
3. Disease can reduce health by disrupting the normal functioning of cells, tissues or organs.
4. Poor health can increase the likelihood of disease because factors such as poor diet, lack of exercise and harmful substances can weaken body systems or increase risk.
5. Disease can interfere with normal body functions by damaging cells, disrupting organ function or preventing normal metabolic processes.
6. Health and disease are closely related because disease can reduce health, while factors affecting health can influence the likelihood of developing disease.

B6.3b — describe different types of diseases

1. A communicable disease is a disease caused by a pathogen that can be transmitted between organisms.
2. A non-communicable disease is a disease that cannot normally be transmitted between individuals.
3. Communicable diseases can be transmitted between organisms by pathogens, whereas non-communicable diseases are not caused by transmissible pathogens.
4. Communicable diseases can spread through routes such as airborne droplets, direct contact, contaminated food or water, sexual contact and vectors.
5. Non-communicable diseases are not normally transmitted because they are generally caused by genetic, lifestyle or environmental factors rather than transmissible pathogens.
6. An example of a communicable disease is influenza, while an example of a non-communicable disease is coronary heart disease.

B6.3c — describe the interactions between different types of disease

1. HIV attacks cells of the immune system, particularly helper T cells, reducing the body's ability to defend itself against pathogens.
2. HIV can increase susceptibility to other diseases because it weakens the immune system, making it harder for the body to fight infections.
3. Tuberculosis (TB) is a communicable disease caused by the bacterium Mycobacterium tuberculosis, which commonly affects the lungs.
4. HIV weakens the immune system, making a person more susceptible to developing tuberculosis and making TB infections more difficult to control.

5. Persistent infection with certain types of human papillomavirus (HPV) can cause changes in cervical cells that may develop into cervical cancer.
6. Infection with high-risk HPV can increase the risk of cervical cancer because viral infection can cause abnormal changes in cervical cells, which may become cancerous.

B6.3d — explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals and plants

1. The four main types of pathogen are viruses, bacteria, protists and fungi.
2. Viruses can spread between animals and plants through methods including airborne droplets, direct contact, body fluids and vectors.
3. Bacteria can spread through air, water, food, direct contact, contaminated surfaces and vectors.
4. Protists can be spread by vectors such as mosquitoes, while fungi can spread through airborne spores, direct contact or contaminated material.
5. The number of pathogens and number of infected cases can be monitored over time to identify changes in the spread and prevalence of a communicable disease.
6. The number of infected cases can be estimated by sampling a population, identifying infected individuals and using the sample results to estimate the number infected in the wider population.

B6.3e — explain how the spread of communicable diseases may be reduced or prevented in animals and plants

1. Detecting an antigen can identify a pathogen because antigens are molecules associated with the surface of pathogens and can be detected using specific antibodies.
2. DNA testing can detect a communicable disease by identifying specific DNA sequences belonging to the pathogen in a sample.
3. Plant diseases can be detected by examining plants for visible symptoms, such as unusual spots, discolouration, distorted growth or abnormal leaves.
4. Early detection allows infected individuals or plants to be isolated or treated quickly, reducing opportunities for the pathogen to spread.
5. Comparing the number of infected cases before and after control measures can show whether the measures have reduced disease transmission.
6. Spread can be reduced through measures such as vaccination, isolation, hygiene, controlling vectors, using appropriate medicines, removing infected plants and controlling movement of infected organisms.

B6.3f — describe a minimum of one common human infection, one plant disease and sexually transmitted infections in humans including HIV/AIDS

1. Influenza is a common human viral infection caused by the influenza virus.
2. Tuberculosis (TB) is a common human bacterial infection caused by the bacterium Mycobacterium tuberculosis.
3. Athlete's foot is a common fungal infection caused by a fungus.
4. Tobacco mosaic virus (TMV) is a viral plant disease caused by a virus that can cause a characteristic mosaic pattern on leaves and reduce photosynthesis.
5. Barley powdery mildew is a fungal disease caused by a fungus, while crown gall disease is caused by the bacterium *Agrobacterium*.
6. HIV/AIDS is caused by the human immunodeficiency virus (HIV), which attacks the immune system. HIV can be transmitted sexually through infected body fluids during unprotected sexual contact.

B6.3g — explain how white blood cells and platelets are adapted to their defence functions in the blood

1. White blood cells defend the body by detecting and destroying pathogens and producing substances that help protect against infection.
2. The three main defence functions are phagocytosis, antibody production and antitoxin production.
3. During phagocytosis, a white blood cell surrounds and engulfs a pathogen, enclosing it inside the cell before digesting it using enzymes.
4. Antibodies bind specifically to antigens on pathogens, helping to destroy or neutralise them. Antitoxins neutralise toxins produced by pathogens.
5. Platelets help blood to clot when blood vessels are damaged, preventing excessive blood loss and helping prevent pathogens from entering the body.
6. Platelets gather at damaged blood vessels and help form a blood clot, creating a barrier that seals the wound and reduces the entry of pathogens.

B6.3h — describe the non-specific defence systems of the human body against pathogens

1. A non-specific defence system protects the body against a wide range of pathogens rather than targeting one specific pathogen.
2. The skin acts as a physical barrier that prevents pathogens from entering the body and produces substances that can inhibit microbial growth.

3. Hairs in the nose trap particles and pathogens, while mucus traps them so they can be removed from the respiratory system.
4. Cilia are hair-like structures that move mucus containing trapped pathogens towards the throat, where it can be swallowed.
5. Hydrochloric acid in the stomach creates a highly acidic environment that kills many pathogens entering the digestive system.
6. Blood clotting seals damaged skin and blood vessels, preventing further blood loss and reducing the opportunity for pathogens to enter the body.

B6.3i — explain the role of the immune system of the human body in defence against disease

1. The immune system recognises and destroys pathogens and helps protect the body against infectious disease.
2. White blood cells recognise pathogens by detecting foreign antigens on their surfaces.
3. Antibodies bind specifically to pathogen antigens and can neutralise pathogens or mark them for destruction.
4. Antitoxins bind to and neutralise toxins produced by pathogens, reducing their harmful effects.
5. Antibodies produced against a pathogen can remain available through memory cells, allowing a faster and stronger response if the same pathogen enters the body again.
6. The immune response is specific because antibodies and immune cells recognise particular antigens found on specific pathogens.

B6.3j — explain the use of vaccines and medicines in the prevention and treatment of disease

1. Vaccines introduce antigens from a pathogen into the body, stimulating an immune response without causing the disease. This produces memory cells that provide protection against future infection.
2. Vaccination stimulates the production of specific antibodies and memory cells, allowing a faster and stronger response when the pathogen is encountered again.
3. An antibiotic is a medicine used to treat bacterial infections, whereas an antiviral is a medicine used to target viruses or reduce their replication.
4. Antibiotics work against bacteria, which have cellular structures and processes that can be targeted by these drugs, but viruses reproduce inside host cells and do not have the same structures.
5. Antiseptics are substances that kill or inhibit microorganisms and are applied to skin or wounds to reduce the risk of infection.

6. Antibiotics treat bacterial infections, antivirals can reduce viral replication and antiseptics reduce microorganisms on body surfaces or wounds, helping prevent infection.

B6.3k — describe the processes of discovery and development of potential new medicines

1. Preclinical testing determines whether a potential medicine is sufficiently safe and potentially effective before it is tested on humans.
2. Clinical testing investigates the safety, effectiveness and appropriate dosage of a medicine in humans.
3. Preclinical testing investigates factors such as toxicity, effectiveness and appropriate dosage, initially using laboratory tests and sometimes animals.
4. Clinical testing investigates safety, effectiveness, dosage and side effects in human volunteers and patients.
5. Testing is necessary to establish that a medicine is safe enough and effective enough before it is widely used.
6. Aseptic techniques are used to prevent unwanted microorganisms contaminating bacterial cultures, ensuring that observed growth is due to the bacteria being investigated.

B6.3l — recall that many non-communicable human diseases are caused by the interaction of a number of factors

1. Incidence is the number of new cases of a disease occurring in a population over a specified period.
2. Regular exercise can reduce the incidence of some non-communicable diseases by reducing risk factors such as obesity and cardiovascular disease.
3. A diet high in saturated fat, salt or sugar can increase the risk of diseases such as cardiovascular disease, type 2 diabetes and obesity.
4. Excessive alcohol consumption can increase the risk of liver disease, cardiovascular disease and some cancers.
5. Smoking increases the risk of lung disease, cardiovascular disease and lung cancer, among other conditions.
6. The incidence of non-communicable diseases can differ between populations because of differences in lifestyle, diet, genetics, environmental conditions, healthcare and socioeconomic factors.

B6.3m — evaluate some different treatments for cardiovascular disease

1. Lifestyle changes include increasing exercise, eating a balanced diet, stopping smoking and reducing alcohol consumption.
2. Medical treatments include statins, drugs that reduce blood pressure and drugs that reduce blood clotting.
3. Surgical treatments include stents, coronary artery bypass surgery and heart valve replacement.
4. Lifestyle changes can reduce risk factors such as high blood pressure, high cholesterol and obesity, reducing the risk or effects of cardiovascular disease.
5. Medical treatments can reduce cholesterol, lower blood pressure or prevent blood clots, reducing the risk of serious cardiovascular events.
6. Surgical treatments can restore or improve blood flow and heart function, but they can involve risks such as infection, bleeding and complications from surgery.

B6.3n — analyse the effect of lifestyle factors on the incidence of non-communicable diseases at local, national and global levels

1. Incidence is the number of new cases of a disease occurring in a population during a specified period.
2. Regular exercise generally reduces the risk and incidence of several non-communicable diseases, including cardiovascular disease and type 2 diabetes.
3. A poor diet, particularly one high in saturated fat, salt and sugar, can increase the incidence of diseases such as cardiovascular disease and type 2 diabetes.
4. Excessive alcohol consumption increases the risk and incidence of conditions including liver disease, cardiovascular disease and some cancers.
5. Smoking increases the incidence of lung cancer, cardiovascular disease and chronic lung diseases.
6. Incidence can differ between local, national and global populations because lifestyle factors such as diet, smoking, alcohol consumption and exercise vary between populations, along with genetic, environmental and socioeconomic factors.

B6.3o — describe cancer as the result of changes in cells that lead to uncontrolled growth and division

1. Cancer is a disease caused by changes in cells that result in uncontrolled growth and division.
2. Changes to genes controlling cell growth and division can cause cells to divide when they should not.

3. Uncontrolled cell growth means cells continue to increase in number or size without normal regulation.
4. Uncontrolled cell division means cells continue to divide repeatedly without the normal controls that regulate the cell cycle.
5. Uncontrolled growth and division can cause a mass of abnormal cells to form a tumour.
6. Normal cell growth and division are controlled and regulated, whereas cancer cells can divide uncontrollably and may form tumours.

B6.3p — discuss potential benefits and risks associated with the use of stem cells in medicine

1. Stem cells are unspecialised cells that can divide and differentiate into specialised cell types.
2. Stem cells can be used to produce replacement cells or tissues that can be used in tissue transplantation to replace damaged or diseased tissue.
3. A potential benefit is that stem cells could replace damaged cells and restore the function of tissues or organs, potentially treating diseases that currently have limited treatment options.
4. A potential risk is uncontrolled cell division, which could result in tumour formation.
5. Tissue rejection can occur when the recipient's immune system recognises transplanted cells as foreign and attacks them.
6. Tissue rejection can damage or destroy transplanted cells, reducing the effectiveness and success of the treatment.

B6.3q — explain some of the possible benefits and risks of using gene technology in medicine

1. Gene technology involves modifying or manipulating an organism's genetic material to produce a desired effect.
2. A potential benefit is the ability to treat genetic disorders by replacing, modifying or introducing genetic information.
3. Gene technology could be used to introduce a functional version of a faulty gene, allowing cells to produce a functional protein and reducing the effects of a genetic disorder.
4. A potential risk is that genetic modification could cause unintended changes, potentially producing harmful effects.
5. Practical considerations include the cost, effectiveness, safety, availability and long-term effects of gene technology.
6. Ethical considerations include whether it is acceptable to alter human genetic material, the possibility of unequal access to treatment and concerns about unintended effects on individuals or future generations.

B6.3r — discuss the potential importance for medicine of our increasing understanding of the human genome

1. The human genome is the complete set of genetic material in a human, including all of its genes and DNA sequences.
2. Knowledge of the human genome can help identify genetic variants associated with particular diseases, allowing doctors to estimate an individual's risk of developing certain conditions.
3. Genome information can help doctors choose treatments based on an individual's genetic characteristics, potentially improving effectiveness and reducing adverse effects.
4. Genome-targeted drugs are medicines designed to act on specific molecular targets associated with particular genetic characteristics or disease-causing changes.
5. Genome-targeted drugs could improve treatment by targeting disease processes more precisely, potentially increasing effectiveness and reducing effects on healthy cells.
6. Increasing understanding of the human genome could enable earlier diagnosis, improved prediction of disease risk, personalised treatments and development of new medicines, potentially improving prevention and treatment of disease.