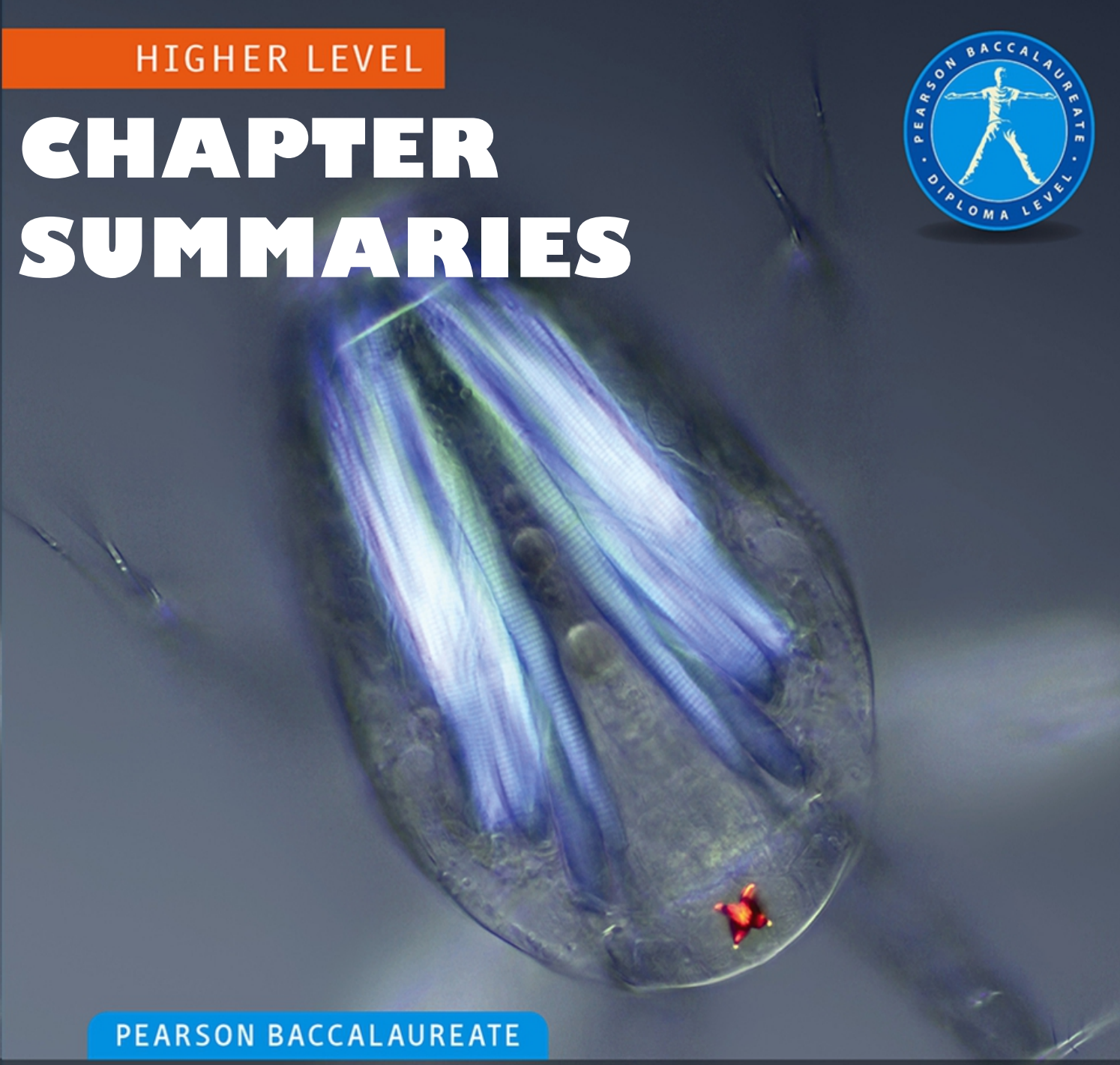
HIGHER LEVEL

CHAPTER SUMMARIES



PEARSON BACCALAUREATE

HIGHER LEVEL

Biology

2nd Edition

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Chapter 1: Cells

1 The cell theory states that living organisms are composed of cells, that cells are the smallest unit of life, and that cells come from pre-existing cells.

2 Scale bars or stated magnifications enable you to determine the actual size of specimens.

3 It is essential that a high surface area to volume ratio exists for a cell. As a cell increases in size, the volume increases much faster than the surface area, thus decreasing the surface area to volume ratio. This decreases the chances of the successful existence of the cell.

4 Cells show emergent properties. This means that the interaction of the parts of the cell results in the whole being greater than the sum of its parts.

5 In multicellular organisms, cells differentiate to carry out specialized functions. This specialization occurs as a result of differential expression of genes in a multicellular organism.

6 Stem cells have yet to go through the differentiation process. Thus they maintain the ability to differentiate along different pathways. There appear to be stem cells in most major types of tissues.

7 Stem cells have many therapeutic uses, including the replacement of damaged bone marrow cells in leukaemia patients. In the future, it may be possible to treat conditions such as Alzheimer's disease and Parkinson's disease with stem cells.

8 Prokaryotic cells have ribosomes, a cell wall, a cell membrane, a nucleoid region, and, in most cases, plasmids. These simple cells divide by binary fission.

9 DNA exists in the nucleoid region of prokaryotic cells. It is circular in form and is not associated with proteins.

10 Membrane-bound organelles, including a nucleus, are associated with eukaryotic cells.

11 Eukaryotic cells exhibit much more compartmentalization than prokaryotic cells. This allows certain areas to carry out specialized and highly efficient functions. Organelles best demonstrate this compartmentalization, and include mitochondria, chloroplasts, nuclei, vacuoles, Golgi apparatus, endoplasmic reticulum, and lysosomes.

12 The eukaryotic cells of animals contain centrioles, while the eukaryotic cells of plants do not. Plant cells contain chloroplasts, animal cells do not. Plant cells have cell walls, animal cells do not. Plant cells have larger vacuoles than animal cells.

13 Cell membranes include phospholipids and proteins. These proteins may be classified as integral or peripheral, depending on their location.

14 The hydrophobic and hydrophilic properties of the cell membrane are the result of the chemical nature of the phospholipid bilayer.

15 Examples of passive transport, which does not require any cellular energy, include diffusion, facilitated diffusion, and osmosis. Examples of active transport, which does require the expenditure of cellular energy, include endocytosis, exocytosis, and the sodium–potassium pump.

16 It is essential that the plasma membrane has a degree of fluidity so that shape changes can occur to allow endocytosis and exocytosis.

17 'Concerns' of the cell theory include the multinucleated cells of muscle cells, fungal hyphae, and some green algae. Also, the characteristics of viruses raise some questions concerning cell theory. The 'first' cell always presents a problem for the cell theory.

18 At present, the endosymbiotic theory is the most accepted explanation for the development of eukaryotic cells from prokaryotic cells. This theory states that, about 2 billion years ago, a bacterium took up residence inside a very simple eukaryotic cell. The theory goes on to say that this was the first step in the development of the organelles we see today in eukaryotic cells.

19 Cell division allows the production of two identical daughter cells. Cell division involves both mitosis, a nuclear division, and cytokinesis, a cytoplasmic division.

20 Cancer involves cells whose cell cycles are out of control. Mutagens, oncogenes, and metastasis are all terms commonly associated with cancer.

21 Cyclins are a group of proteins that control a cell's progression through the cell cycle. The cell cycle involves interphase, in which the cell is busy carrying out the functions for which it is designated through differentiation. Metabolic activities such as protein synthesis, DNA replication, and organelle reproduction occur in this phase. Interphase includes the smaller phases known as G_1, S, and G_2.

22 The four stages of mitosis are prophase, metaphase, anaphase, and telophase. During prophase and metaphase the chromosome is actually two molecules of DNA attached together at the centromere. Each molecule of DNA is called a chromatid.

23 The DNA in the nucleus of eukaryotic cells goes through a process called supercoiling to form the chromosomes that enter into mitosis. This supercoiling involves DNA wrapping around spherical proteins called histones to form nucleosomes.

Chapter 2: Molecular biology

1 Living organisms and the cells that comprise living organisms are a complex set of interacting chemicals and chemical reactions.

2 Water molecules are polar and thus have a relatively negative end (where oxygen is located) and a relatively positive end (where the hydrogens are located).

3 Many of the properties of water are explained by its polarity. These properties include being a solvent for other polar molecules, cohesion between water molecules, and also a variety of thermal properties.

4 Carbohydrates are organic molecules composed of carbon, hydrogen, and oxygen at or near the ratio of $C_nH_{2n}O_n$, where n = the number of carbon atoms.

5 The 'building blocks' of large organic molecules are often called monomers. Think of the smallest carbohydrates (or monomers) as being 'single sugar units'. Monosaccharides are single sugar units, disaccharides are two-sugar units and polysaccharides are many sugar units in size. Lipids are also known as fats and oils. A typical lipid, called a triglyceride, is composed of one molecule of glycerol bonded to three molecules called fatty acids. Proteins are molecules composed of many amino acids bonded together.

6 Condensation reactions covalently bond smaller organic molecules together to form larger organic molecules. Hydrolysis reactions reverse this by breaking the larger organic molecules apart into the original smaller molecules.

7 The building block units of DNA molecules are called nucleotides. Each nucleotide is composed of a monosaccharide sugar, a phosphate group, and one of four possible nitrogenous bases (adenine, thymine, cytosine, or guanine).

8 DNA is composed of two strands of nucleotides. These two strands are held together by hydrogen bonding between complementary bases. Together, they form an overall double helix geometric shape.

9 The complementary base pairs of DNA are:

- adenine and thymine
- cytosine and guanine.

10 DNA replicates in a semi-conservative pattern in which each of the two strands of DNA is used as a template for the formation of a new strand. Thus, all newly formed DNA molecules are actually one half old DNA and one half new DNA.

11 Proteins are synthesized using a two-step process. First, a strand of DNA is used as a template to create an messenger (m)RNA molecule in a process called transcription. Second, this mRNA molecule, with the help of a ribosome, transfer (t)RNA, and amino acids, synthesizes the actual protein in a process called translation.

12 The genetic code is written in sequences of three bases along the DNA molecule. Each sequence of three bases is called a triplet.

13 Some proteins act as organic catalysts within cells and are called enzymes. Each enzyme typically has a single substance that it is 'specific for' and that substance is called the enzyme's substrate. As enzymes are complex proteins, they are affected by variation in temperature, pH, and substrate concentration.

14 Cell respiration is common to all cells and explains how a cell derives energy in the form of ATP molecules using organic molecules, such as glucose, as a fuel. Some cells use a relatively inefficient form of cell

respiration called anaerobic respiration, and others a much more efficient form called aerobic cell respiration. Efficiency in this case is determined by how many ATP molecules are derived from a single fuel molecule (glucose).

15 Photosynthesis is a two-stage process whereby light energy is first converted into chemical energy and then that chemical energy is used to 'fix' carbon dioxide into an organic molecule such as glucose. These two stages are called the light-dependent reactions and the light-independent reactions, respectively.

Chapter 3: Genetics

1 Humans have 23 pairs of chromosomes that are made up of long strings of DNA and constitute approximately 22,000 genes.

2 A gene is a heritable factor that controls a specific characteristic or trait such as blood type or skin colour.

3 Mutations occur regularly and add variations to the genome; one example is the base substitution that causes sickle cell anaemia.

4 Another process that adds variety in the human population is meiosis: a reduction division used to produce haploid gametes.

5 A genetic anomaly such as a non-disjunction can cause a child to receive three chromosomes instead of two, as in the case of Down syndrome. After an amniocentesis, a karyogram of an unborn child can be prepared to determine whether a non-disjunction has occurred or not.

6 A Punnett grid can be used to see all the possible combinations of a monohybrid cross of a given set of parents' alleles, whether they are dominant or recessive.

7 Special rules must be followed in order for a Punnett grid to work: letters must be chosen to represent the alleles, the parents' genotypes must be determined correctly, the parents' gametes must be clearly identified, and the grid, once filled in, must be interpreted using per cent chances or theoretical proportions of offspring.

8 There are some special cases for monohybrid crosses, one of which is the ABO blood group system, which shows both multiple alleles and co-dominance.

9 Some genes are carried on the X or Y chromosome (chromosome 23 in humans) and can therefore affect one sex more than the other (XX for females; XY for males): such characteristics are said to be sex-linked. An autosomal condition is one where the genes are found on chromosomes 1 to 22 (called the autosomes) and it does not affect one sex more than another.

10 Particular combinations of letters are used to show special cases, for example $\mathbf{I^A}$, $\mathbf{I^B}$, and **i** for the alleles of ABO blood types, $\mathbf{X^B}$, $\mathbf{X^b}$, and **Y** for colour blindness alleles, and $\mathbf{Hb^S}$ and $\mathbf{Hb^A}$ for sickle cell anaemia.

11 Polymerase chain reaction (PCR) is a technique used on small quantities of DNA (from a crime scene, for example) to make millions of copies so that the sample can be analysed.

12 DNA profiling is a technique used to identify the origin of a sample of DNA by using gel electrophoresis to match up fragments of the unknown DNA with DNA that has already been identified.

13 The Human Genome Project has succeeded in using DNA sequencers to make a map of all the nitrogenous bases that make up the 46 human chromosomes: this will allow researchers to locate base sequences that might be responsible for genetic diseases, which might then code for beneficial molecules that could be used as medications in the future, or which are shared by different populations thus showing ancestries and migration patterns.

14 In recent decades, scientists have developed laboratory techniques to cut, copy, and paste genes to engineer bacteria, plants, and animals with desirable genetic traits; this is the case with genetically modified *Escherichia coli* bacteria used to produce human insulin.

15 There are natural and artificial techniques of cloning. Binary fission, budding, and asexual reproduction in plants using techniques such as rooting stem cuttings, result in new individuals that are identical to their parent. Artificial cloning includes reproductive cloning (making a copy of an entire organism) and therapeutic cloning (making copies of certain cells). These laboratory techniques have something in common with genetically engineered organisms: they carry challenging ethical considerations that no previous generation has had to face.

Chapter 4: Ecology

1 Ecology is the study of relationships between living organisms and between organisms and their environment.

2 The term 'species' is difficult to define: the common definition 'a group of organisms that have similar characteristics and that can interbreed to produce fertile offspring' can be challenged in several ways.

3 Populations of species live in communities that occupy a specific habitat: these populations live in and interact with their environment, thus constituting ecosystems.

4 Populations of plants are difficult to estimate so sampling techniques must be used to measure part of the population and estimate the size. Quadrats can be used for random sampling, or a transect can be used for systematic sampling.

5 Food chains and food webs use a series of arrows to show the ecological relationships between organisms: the term 'relationship' can be thought of here as 'who eats whom'.

6 Trophic levels are used to enumerate the steps taken as energy is passed along a food chain: the first trophic level is occupied by the producers (autotrophs), the second level is occupied by the primary consumers (types of herbivore), the third trophic level is occupied by a secondary consumer (a heterotroph that eats the herbivore), etc.

7 While water and minerals are constantly recycled, energy is not: in a typical food chain, energy starts as sunlight, is transformed into chemical energy by autotrophs, and flows through the food chain. However, the system is highly inefficient and most energy is lost rather than being passed on. This can be seen in a pyramid of energy.

8 A pyramid of energy is drawn as a stepped pyramid, with each level passing on approximately 10% of the energy. The unit of energy is kilojoules per square metre per year.

9 Food webs must constantly recycle minerals: this job is done by decomposers that break down non-living organic material, thus unlocking simpler compounds that are useful to other organisms.

10 Carbon is an essential chemical element in the biosphere and it is recycled between the air, soil, and living organisms in a process called the carbon cycle.

11 Carbon in the environment can be found in multiple molecules of interest to biologists, notably carbon dioxide in the atmosphere or dissolved in the oceans, organic compounds in living organisms or their waste products, petroleum products in fossil fuels, and calcium carbonate used by marine organisms such as corals.

12 Peat is a naturally forming energy-rich substance found in wetlands that can be dried and burned as fuel in a similar manner to fossil fuels.

13 Fossil fuels such as coal, natural gas (methane), and gasoline are being burned at increasing rates by human activities such as electricity production and transportation. The combustion of these organic substances is releasing large quantities of carbon dioxide into the air. The carbon cycle is being pushed off balance by such human activities.

14 The greenhouse effect is a natural phenomenon that keeps the Earth's surface warm by letting in light energy, converting the light energy to heat energy, and retaining the heat in the same way the glass of a greenhouse does.

15 The enhanced greenhouse effect is an intensification of this effect caused by human activities such as burning fossil fuels. According to the International Panel on Climate Change, this increase in human activity is modifying the Earth's climate and causing ecosystems to be pushed out of balance. The debate that needs to take place in society is how we are going to react to these problems in the coming decades.

Chapter 5: Evolution and biodiversity

1 Evolution is the process of cumulative change in the heritable characteristics of a population. The evidence for evolution can be seen in:

- the fossil record, which shows continual changes in organisms over time
- the selective breeding of domesticated animals to produce varieties that did not exist before
- homologous structures, such as the pentadactyl limbs of whales, humans, and bats.

2 Evolution by natural selection as proposed by Darwin and Wallace follows these steps:

- there is an overproduction of offspring, generating a competition for resources
- there is variation within populations, allowing some offspring to have a slight advantage over others
- individuals that possess characteristics that are poorly adapted for their environment tend to be less successful at surviving and therefore at finding a mate
- individuals that possess characteristics that are well adapted for their environment tend to be more successful at surviving, finding a mate, and passing on their genetic characteristics to the next generation
- after many generations, slight changes can accumulate to a point where the current generation is very different from its ancestors.

3 Half-life is the amount of time it takes for half of the radioactive parent isotopes in a rock or fossil to decay into stable isotopes: the most common radioisotopes used in determining the age of a rock or fossil are carbon-14 (with a half-life of 5730 years) and potassium-40 (with a half-life of 1.3 billion years).

4 Examples of natural selection in modern times include antibiotic resistance in bacteria and pesticide resistance in rats.

5 Every organism identified on Earth has a scientific name based on the binomial nomenclature system: the first name is the genus and the second name is the species.

6 Archaea is one of three domains into which all life is categorized. The other two are Eubacteria and Eukaryote. These three domains are divided up into phyla.

7 Various plant and animal phyla have been characterized and you should be familiar with the features that distinguish the following: Bryophyta, Filicinophyta, Coniferophyta, Angiospermophyta, Porifera, Cnidaria, Platylhelmintha, Annelida, Mollusca, Arthropoda, and Chordata. You should also know the characteristics of the classes of birds, mammals, amphibians, reptiles, and fish.

8 Dichotomous keys can be used to help identify the kingdom, phylum, class, order, family, genus, and species that an organism belongs to.

9 Biochemical evidence for a common ancestry includes:

- the universality of DNA
- the fact that all proteins found in living organisms use the same 20 amino acids
- the fact that all amino acids are left-handed.

10 By comparing the DNA sequences of species, it is possible to see which ones are the most similar to each other, suggesting a recent common ancestor. Two very dissimilar samples of DNA would suggest a more distant phylogenetic connection. The number of differences can be used as a kind of evolutionary clock to see which speciations were more recent than others.

11 Cladistics is a system of classification that groups taxa together according to the characteristics that have evolved most recently. Cladograms are used to represent these groups (called clades) visually.

12 To construct a cladogram, several characteristics are examined; these characteristics can be analogous, homologous, primitive, or derived.

13 Organisms can have more than one variation in their appearance; these variations are called polymorphisms. Transient polymorphism happens when one variation of an organism appears more frequently than another for a limited period of time and then returns to its original form; an example is the peppered moth.

14 Adaptive radiation occurs when many similar but distinct species evolve relatively rapidly from a single species or from a small number of species, as seen in Darwin's finches on the Galapagos Islands, and in the lemurs of Madagascar and the Comoro Islands.

Chapter 6: Human physiology

1 Food molecules are often in the form of macromolecules such as protein, starch, and lipids. These require digestion by way of hydrolysis reactions aided by a variety of enzymes that enable the reactions to occur at normal (homeostatic) body temperature, 37°C. Contractions of the small intestine mix food with enzymes and keep the food moving through the gut.

2 Absorption occurs primarily in the small intestine, a long tube that has a huge surface area for absorption due to the presence of multicellular villi and cellular microvilli.

3 The human heart acts as a double pump. The right side of the heart pumps deoxygenated blood to the lungs (pulmonary circulation) and the left side pumps oxygenated blood to the body's capillaries (systemic circulation).

4 When a human is 'at rest', each heart beat is initiated by a group of cells within the right atrium known as the sinoatrial (SA) node. The SA node is also known as the 'pacemaker'.

5 Arteries are relatively thick with smooth muscle in their walls; veins are relatively thin but have large internal diameters. Capillaries are very, very thin (one cell layer thick) and are the only blood vessels that allow molecular exchanges in to and out of the bloodstream.

6 The best defence against organisms that cause infectious disease is to prevent their entry into the body. Skin and the mucous membranes are extremely important in this role. Cuts are quickly sealed by clots in order to prevent blood loss and entry by pathogens.

7 Many foreign proteins on invading microorganisms are recognized by specific leucocytes as 'not-self' and thus act as antigens for an immune response. Among other responses, a specific type of protein antibody is produced by specific lymphocytes in response to recognition of a specific antigen.

8 Antibiotics are chemicals that selectively work against bacterial (prokaryotic) cells but those same chemicals have no effect on body (eukaryotic) cells. Viruses are not affected by antibiotics as they are not cells of any kind.

9 Human lungs are designed for efficient gas exchange (oxygen and carbon dioxide). Much of this efficiency results from numerous microscopically small alveoli within the lungs where the gas exchange actually occurs.

10 Our nervous system sends and receives messages in the form of action potentials. An action potential is created when ions are actively transported in and out of the neurone and then suddenly allowed to diffuse according to their concentration gradients. This action occurs in a fraction of a second and represents one very small 'piece' of nervous system information.

11 Neurones communicate with each other when a chemical called a neurotransmitter is released from one neurone (the presynaptic neurone) and is received by another neurone (the postsynaptic neurone). This synaptic transmission is not always just between two neurones: multiple neurones can be involved.

12 Homeostasis is the body's attempt to keep factors such as temperature and blood sugar within a normal range. Homeostasis is typically designed around a negative feedback mechanism where a factor (e.g. body temperature) that is beginning to leave its normal range triggers a response that brings it back closer to the midpoint of the range or set-point.

13 Diabetes is not a single disease. Type I diabetes is an autoimmune disease in which the immune system destroys the cells within the pancreas that produce insulin. Type II diabetes is much more common; it often shows up later in life and is typically a result of body cells no longer responding to insulin as they once did.

14 The purpose of the female menstrual cycle is to prepare the uterus (thicken the endometrium with blood vessels) in case there is a fertilization and thus a need for an early embryo to implant itself in the endometrium. This can then lead to the successful formation of a placenta.

15 Sex hormones, such as oestrogen, progesterone, and testosterone, are first influential during embryonic development in forming either male or female body parts. At puberty, the sex hormones are responsible for changes in the body known as secondary sex characteristics.

Chapter 7: Nucleic acids

1 The nucleotides of DNA are attached by covalent bonds involving phosphate between the 5′ and 3′ carbons to form a single strand. Two strands of nucleotides are held together by hydrogen bonds between complementary bases to form the double helix shape.

2 The relatively weak hydrogen bonds between the two DNA strands allow the molecule to open so that the nucleotide code can be available for DNA replication or transcription. The DNA strands are said to be antiparallel to one another.

3 DNA nucleotides include the pentose known as deoxyribose, a nitrogen-containing base, and at least one phosphate functional group.

4 Two hydrogen bonds occur between thymine and adenine. Three hydrogen bonds occur between cytosine and guanine.

5 In eukaryotic cells, DNA is wrapped around molecules of protein called histone to allow the formation of nucleosomes. These nucleosomes allow the supercoiling and condensation of chromatin into chromosomes.

6 DNA replication occurs in a 5′ to 3′ direction and involves semi-conservative replication. An experiment carried out by Meselson and Stahl confirmed the semi-conservative replication model of DNA replication.

7 The enzymes of DNA replication are helicase, RNA primase, DNA polymerase III, DNA polymerase I, and DNA ligase. Terms associated with DNA replication include leading and lagging strands, Okazaki fragments, and RNA primer.

8 There are three types of RNA: messenger, transfer, and ribosomal. RNA is a single-stranded nucleic acid made up of monomers of ribonucleotides that include ribose sugar, a phosphate, and a nitrogen-containing base.

9 Polypeptide or protein synthesis involves two processes, transcription and translation. Transcription occurs in the nucleus of the cell, while translation occurs in the cytoplasm at the ribosomes.

10 Transcription involves the transfer of the appropriate DNA nucleotide code onto messenger RNA. Messenger RNA contains a code made up of three base ‘words’ known as codons. Messenger RNA is changed from primary mRNA to mature mRNA before it leaves the nucleus to go to the cytoplasm.

11 Transcription occurs at transcription bubbles and involves producing the messenger RNA from the antisense strand of DNA. RNA polymerase is the major enzyme involved in this process.

12 Translation occurs at the ribosomes in the cytoplasm. The end result of translation is a polypeptide/protein produced in the amino acid sequence dictated by the DNA in the nucleus.

13 DNA is said to contain information in triplets. Messenger RNA is said to contain information in codons. Transfer RNA has anticodons that go through complementary base pairing with the messenger RNA.

14 The genetic code is said to be universal and degenerate. It is also often referred to as being unambiguous because the code is essentially the same in all organisms on Earth.

15 All proteins have a primary and secondary structure. Fibrous proteins do not contain a tertiary structure. The quaternary structure of a protein involves multiple protein chains, but not all proteins have this structure. The primary structure in proteins refers to the sequence of amino acids. It is the primary structure that determines the position of hydrogen bonds and other electrostatic forces that then cause the higher structures.

16 Proteins may be classified as polar or non-polar. They may also be classified as fibrous or globular.

Chapter 8: Metabolism, cell respiration, and photosynthesis

1 Enzymes speed up both anabolic and catabolic reactions without being changed themselves. The way they work is explained by the 'induced-fit model'. This model is different from the 'lock-and-key' model in that the enzyme's active site and the substrate change shape when they come into contact with one another, allowing a fit. The original lock and key model did not account for this conformational change to allow a fit.

2 Activation energy is the energy necessary to destabilize chemical bonds in a substrate in order to bring about some change.

3 In competitive inhibition, a molecule called a competitive inhibitor competes directly for the active site of an enzyme. In non-competitive inhibition the inhibitor does not compete for the enzyme's active site. Instead, it combines with the allosteric site, bringing about a change in conformation of the active site and enzyme inhibition.

4 Metabolic pathways are series of reactions ultimately producing some product for the organism/cell. When a product is present in sufficient quantity, end-product inhibition occurs in most cases at the first reaction in the series. This prevents further production of the material. This is a form of negative feedback.

5 Oxidation happens whenever the following occur: loss of electrons, gain of oxygen, loss of hydrogen, or a compound is formed that has a lower potential energy than the original. Reduction happens whenever the following occur: gain of electrons, loss of oxygen, gain of hydrogen, or a compound is formed with higher potential energy than the original. If a compound is oxidized, another substance must be reduced. This is referred to as a redox reaction. Oxidation results in C–H bonds, while reduction results in C–O bonds.

6 Cellular respiration is broken down into simpler stages. These stages include glycolysis, anaerobic respiration, and aerobic respiration. Glycolysis occurs in the cytoplasm and is common to both aerobic and anaerobic respiration. Anaerobic respiration, also called fermentation, occurs in the cytoplasm. Aerobic respiration, which includes the link reaction, Krebs cycle, and oxidative phosphorylation, occurs in the mitochondria of the cell.

7 Glycolysis results in a net gain of two molecules of ATP by substrate-level phosphorylation. The two final molecules produced by glycolysis are three-carbon molecules called pyruvate. Glycolysis also enables the formation of two reduced molecules of NAD.

8 Once the two pyruvate molecules are formed, the next pathway is determined by the presence or absence of oxygen. If oxygen is present, the pyruvate will enter the Krebs cycle and go through aerobic respiration. If no oxygen is present, the pyruvate will stay in the cytoplasm and go through fermentation.

9 Because of the different enzymes present in the cytoplasm of plant and animal cells, the end products of fermentation differ in plant and animal cells. In animal cells, the end products are lactate/lactic acid. In plant cells, the end products are ethyl alcohol and carbon dioxide.

10 The electron transport chain and chemiosmosis are the processes by which most molecules of ATP are produced. These processes occur on the inner mitochondrial membrane and on the membranes of the cristae.

11 Reduced NAD and FAD carry energy released by oxidation to the electron transport chain. The molecules involved in this chain occur on the membranes of the mitochondrial cristae. Oxygen is the final acceptor of the 'de-energized' electrons.

12 Cellular respiration is a catabolic reaction, while photosynthesis is an anabolic reaction. The products of the overall reaction of cellular respiration are essentially the substrates of the overall reaction of photosynthesis. The substrates of the overall reaction of cellular respiration are essentially the products of the overall reaction of photosynthesis.

13 Photosynthesis involves two major stages, the light-dependent reactions and the light-independent reactions. These reactions occur in the chloroplasts of plant cells.

14 Photosystems I and II are involved in the light-dependent reactions of photosynthesis. These photosystems are groups of accessory pigments and chlorophyll *a*. They occur in the membranes of the thylakoids of the chloroplasts.

15 Photosystem II begins the light-dependent reactions and includes the absorption of photons, the photolysis of water, and the excitation of a chlorophyll *a* electron to a higher energy state. This high-energy electron is passed down an electron transport chain involving cytochromes to result in ATP (by chemiosmosis) and a de-energized electron that enters photosystem I.

16 Photosystem I uses this electron to replace the one lost when it absorbs photons of light and produces an energized electron at its reaction centre. This energized electron then moves down an electron transport chain to produce energy-rich NADPH.

17 ATP and NADPH are the final energy-rich products of the light-dependent reactions. They are necessary for the light-independent reactions to occur. Oxygen is released from photosynthesizing cells and in most cases exits the plant via stomata.

18 The light-independent reactions include the Calvin cycle. The Calvin cycle occurs in the stroma of the chloroplast.

19 The Calvin cycle begins and ends with ribulose bisphosphate (RuBP). Two molecules of triose phosphate, released from the Calvin cycle, combine to form one molecule of glucose.

Chapter 9: Plant biology

1 The major parts of a typical root include the epidermis, cortex, endodermis, xylem, phloem, and root hairs. These structures allow the root to carry out its main functions of absorbing mineral ions and water from the soil, anchoring the plant, and, in some cases, providing food storage.

2 The stem of a plant is involved in the transport of materials and the support of the plant above the ground. It also allows the attachment of leaves. Stems contain transporting or vascular tissue including xylem and phloem. Stems may also include an area of meristematic tissue called the cambium. Many stems have a significant amount of supporting tissue that may be called pith or may be made up of a woody-like material.

3 The leaves of a plant usually include a cuticle, upper and lower epidermis, palisade mesophyll, spongy mesophyll, and vascular bundles. Stomata usually occur in the lower epidermis tissue. Leaves are the major photosynthetic organs of a plant.

4 Flowers are the reproductive organs of a group of plants called angiosperms. Angiosperms are also known as flowering plants. Flowers may include sepals, petals, stamens, and carpels or pistils.

5 Water moves into the root via the root hairs, extensions of the epidermis of root epidermal cells. This movement usually occurs because these root cells have a higher solute concentration and a lower water concentration than the surrounding soil. Once in the root hairs, water follows the following pathway: epidermis → cortex → vascular cylinder.

6 Protein pumps may also carry out chemiosmosis in the root epidermal membranes to transport mineral ions and solutes into the root. These pumps require cellular expenditure of ATP to happen.

7 Some plants have a symbiotic relationship with fungal hyphae that serves to increase the uptake of water and minerals into the roots of the plant.

8 Transpiration is water loss from the aerial portions of plants, usually the leaves. As water is lost by transpiration, cohesive and adhesive forces serve to help bring an equal amount of water into the roots.

9 The cohesion–tension theory explains the movement of water and minerals upwards in the xylem of plants using the cohesive and adhesive properties of water. Water's cohesion and adhesion properties are the result of the polar characteristics of the water molecule.

10 The movement of water and dissolved minerals upwards in the plant occurs in the xylem. Xylem does not contain living cells. It is composed of hollow tube-like structures with pores in their walls to allow water movement out of the vessels and into the surrounding cells. Xylem tissue often contains lignin, which provides support to the tissue walls and the plant itself.

11 Turgor pressure is the pressure that occurs inside plant cells. Turgor pressure helps the fluid movement from the roots to the tops of plants. It is also involved in the opening and closing of leaf stomata.

12 The plant leaf is adapted to carry out photosynthesis efficiently. The leaf also has stomata that allow the exit of water from the plant to control the temperature inside the leaf structure. The stomata allow the exit of oxygen and the entry of carbon dioxide. This gas exchange capability is essential to the photosynthetic process.

13 Stomata open and close because of changes in the turgor pressure of the guard cells. Abscisic acid causes potassium ions to move out of guard cells, resulting in stomatal closure. Stomata usually occur on leaves; however, some plants have stomata on their stems.

14 The movement of organic molecules in plants is called translocation. Phloem sap includes mostly water and sucrose. The movement of phloem sap is explained by the pressure-flow hypothesis. This hypothesis involves two distinct locations: one is the source, where carbohydrates are added to the phloem sieve tubes, and the other is the sink, where these carbohydrates exit the phloem sieve tubes for storage or immediate usage by the plant.

15 Sources of carbohydrates in plants typically include the leaves. Sinks typically involve roots and stems.

16 The pressure-flow hypothesis utilizes active transport to move carbohydrates against concentration gradients. Phloem tissue includes sieve tube members and companion cells. The sieve tubes are composed of sieve elements that have pores at their ends to allow continuous movement. Companion cells are alive and provide the ATP necessary for the active transport that occurs in the phloem tissue.

17 Plants show indeterminate growth because of their meristematic tissue. Apical meristems occur at the tips of roots and stems, and cause primary growth. Lateral meristems include vascular cambium and cork cambium, and allow secondary growth, which is the growth in thickness of plant stems and roots. Meristematic tissue also plays a part in many plant tropisms.

18 Auxin is a plant hormone that serves as a growth promoter. Plants that show phototropism (growth towards light) do so when they produce auxin on the light side of the plant stem. The auxin then moves from the light side of the plant to the darker side, causing elongation of the cell walls and movement of the plant stems towards the light.

19 In flowers, pollen grains are produced in the anthers of stamens. They contain the male gametes. Ovules, the female gametes, occur in the ovary of the carpel or pistil. Pollination is the transfer of pollen from the anther to the stigma. Fertilization is the union of the ovule and sperm cells of the pollen grains to produce the zygote and, ultimately, the seed. Seed dispersal refers to how the seed is transported from the flower.

20 Major seed parts are the testa (seed coat), the cotyledons (seed leaves), micropyle (the entry point of pollen tube), radicle (embryonic root), and embryonic shoot.

21 Major events during seed germination include the absorption of water, production of gibberellin by the cotyledons, production of amylase, hydrolysis of starch into maltose, radicle or embryonic root growth, and embryonic shoot growth.

22 Photoperiodic control of flowering refers to the fact that some plants flower based on the length of night. Plants called long-day plants flower when nights are short and days are long. Short-day plants only flower when they receive a longer continuous period of darkness.

23 A pigment called phytochrome appears to be involved in photoperiodism in plants. The inactive phytochrome form (P_r) absorbs more red light during the day, causing an active form known as P_{fr} to be produced.

Chapter 10: Genetics and evolution

1 Chiasmata form when two adjacent non-sister chromatids from two homologous chromosomes break at the same point and exchange segments of genetic material.

2 Thanks to crossing over during prophase I and random orientation during metaphase I, it is highly unlikely that a person could produce the same gamete twice; this makes it essentially impossible for parents to produce future offspring identical to their current offspring.

3 Mendel's law of independent assortment states that, when gametes are formed, the separation of one pair of alleles between the daughter cells is independent of the separation of another pair of alleles.

4 Punnett grids can be used to show dihybrid crosses as well as monohybrid crosses. A dihybrid cross involves two characteristics (e.g. flower colour and seed shape). The expected ratio of offspring in a 4 × 4 Punnett grid showing a dihybrid cross is 9:3:3:1.

5 The chi-squared test can be used to see if there is a statistically significant difference between the expected outcome of a genetic cross and the observed outcome. If a statistically significant difference is found to exist, this would imply that something more than chance is affecting the results.

6 During chiasmata formation, maternal alleles can be switched with alleles found on the paternal adjacent non-sister chromatid.

7 A linkage group refers to genes found on the same chromosome and, as a result, usually passed on together to the next generation; a special notation with horizontal lines is used to show this linkage.

8 As a result of crossing over, sometimes a linkage group can be cut and separated to generate new combinations that did not exist in the parents' chromosomes: such new combinations are called recombinants.

9 Polygenic inheritance involves two or more genes influencing the expression of one trait, such as human height.

10 Continuous variation is when a large array of possible phenotypes can be produced (e.g. height) and statistical analysis of the variation shows a bell-curve distribution. Discontinuous variation is when there are only a few possible phenotypes (e.g. ABO blood types) and statistical analysis of the variation is not likely to show an even distribution around an average value.

11 When a species' gene pool does not change over time, there is no evolution. Large changes in allele frequency over time suggest major evolutionary change.

12 The Hardy–Weinberg equation ($p^2 + 2pq + q^2 = 1$) is used to calculate the frequency of alleles, genotypes, or phenotypes within a population. It was derived by looking at a Punnett grid showing how often each genotype and phenotype arises from a cross between two heterozygotes.

13 Similar populations can start to evolve differently from each other if a barrier divides their gene pools; such barriers can cause geographical, temporal, or behavioural isolation.

14 There are three types of selection: directional, stabilizing, and disruptive. Directional selection is when the frequency of a phenotype is favoured over another, thus altering the mean of the distribution of phenotypes so that it is above or below where it was before. Stabilizing selection is when the extreme genotypes are

selected against and phenotypes close to the mean are selected for. Disruptive selection is when the extremes of a phenotype are selected for and phenotypes near the mean are selected against.

15 There are two opposing theories about the rate of evolution. Gradualism states that the changes in species is a slow, constant process, whereas punctuated equilibrium is a process whereby very fast and dramatic changes in species are followed by long periods of little or no change.

Chapter 11: Animal physiology

1 True immunity is gained when the immune system is challenged by a foreign antigen and responds by cloning appropriate B cells to produce antibodies effective against that antigen. Some of those B cells are memory cells and are long-lived, ready to respond to the same antigen if another infection occurs.

2 A vaccine is a weakened form of a pathogen. This provides the immune system with the antigen molecule(s) of the pathogen without risk of disease symptoms.

3 Monoclonal antibodies are produced by hybrid cells, as a result of the fusion of a specific B cell with a cancerous myeloma cell. The resulting hybridoma cell is cultured and produces a single type of antibody known as a monoclonal antibody.

4 Some antigens result in white blood cells, known as mast cells, to release a chemical known as histamine that results in inflammation and other symptoms. Allergies result when the antigens are part of the everyday environment (such as pollen).

5 The human elbow is an example of a hinge joint. The distal end of the humerus forms a joint with both the radius and ulna of the forearm. The primary antagonistic muscles of the elbow are the biceps (to flex the arm) and the triceps (to extend the arm).

6 Muscles contract when a multitude of alternating actin fibres are pulled centrally by myosin fibres within contracting units called sarcomeres. ATP molecules are used to ready the projecting myosin 'heads' for a power stroke in order to slide the actin fibres.

7 Kidneys filter the blood, keeping the levels of such molecules (e.g. urea), ions, and water within a normal homeostatic range. The maintenance of a normal water balance is known as osmoregulation.

8 The filtering units of kidneys are called nephrons. The blood is filtered under pressure in an area of the nephron known as Bowman's capsule. This is called ultrafiltration and results in the removal of a massive amount of water, ions, and glucose from the blood. Many of these molecules must then be reabsorbed back into the blood in the capillary beds surrounding the nephrons.

9 Much of the reabsorption process occurs within the proximal convoluted tubule, the loop of Henle, and the distal convoluted tubule of the nephron. A variety of active and passive transport mechanisms are used in the reabsorption process.

10 Much of the water is retained in the filtrate until it enters the collecting ducts of the nephrons. If water needs to be retained by the body, the posterior pituitary gland secretes antidiuretic hormone (ADH). This results in the collecting ducts becoming permeable to water, which then exits the collecting duct into the surrounding hypertonic fluid of the medulla region of the kidney. This water is then taken into the surrounding capillary beds.

11 Millions of sperm are produced each day within small tubes called seminiferous tubules in post-puberty male testes. This process is called spermatogenesis and involves mitosis to replace cells and meiosis resulting in haploid cells known as spermatozoa.

12 Ova (in the form of oocytes) begin the process of oogenesis within the ovaries of foetal females. The continuation of meiosis is then delayed until ovulation and fertilization. The final result is the production of a large haploid cell that is fertilized by a very small haploid spermatozoon.

13 A human zygote begins mitotic cell division soon after fertilization and also begins moving down a Fallopian tube towards the uterus. On entering the uterus, a human embryo is typically a hollow ball of about 100 cells and is called a blastocyst.

14 A blastocyst embeds itself into the endometrial uterine wall and begins to form an early placenta. When fully formed, a placenta is a highly vascular structure composed of both maternal and foetal blood vessels. The foetus sends deoxygenated, high-waste blood to the placenta through vessels in the umbilical cord; blood returning to the foetus is oxygenated and nutrient rich.

15 The placenta is also a gland as it secretes both oestrogen and progesterone after forming, and will continue to secrete these two hormones during the rest of the pregnancy.

Chapter 12, Option A: Neurobiology and behaviour

1 During neural development the neural plate folds, closes, and becomes the neural tube. Eventually, the neural tube will elongate and become the brain and spinal cord. Failure of the cord to close in the human embryo results in a condition called *spina bifida*.

2 Neurones differentiate in the neural tube but migrate to a final location. The migration of neurones is a response to chemical stimuli from target cells. Molecules secreted by target cells can be chemoattractive or chemorepellent. The growth cone of the migrating neurone responds to these chemical factors and forms multiple synapses.

3 The developing nervous system can change with experience. As a result of neural pruning, only 50% of the neurones that originated during development will survive into adulthood. The brain has both functional and structural plasticity.

4 Different parts of the brain have different functions. For example, the medulla oblongata contains centres that control the autonomic nervous system (ANS). The two parts of the ANS are the parasympathetic system and the sympathetic system. The sympathetic system is associated with 'fight or flight' while the parasympathetic system takes over when you are in a relaxed state.

5 Brain death can be determined by examining the pupil reflex of the ANS. The pupil reflex is an outward sign of brain activity. The optic nerve receives a message from the retina and connects with the pretectal nucleus of the brainstem. From here, a message is sent to the Edinger–Westphal nucleus, the axons of which run along the oculomotor nerves back to the eye. These nerves synapse at the ciliary ganglion. The axons of the ciliary ganglion stimulate the circular muscles of the iris so that it contracts; this closes the pupil. In the dark, the opposite occurs and the circular muscles relax; this opens the pupil.

6 The cerebral cortex is a larger part of the brain and is more highly developed in humans than in other animals. This is where we perform the tasks of reasoning, language, complex thought, visual processing, motor movement, remembering, and speech. The cerebral cortex has become enlarged as a result of the extensive folding necessary to accommodate it within our cranium. Brain metabolism requires large energy inputs.

7 Sound is received by the ear. The outer ear catches the sound waves and carries them down the auditory canal to the eardrum (tympanic membrane), which moves back and forth slightly. The bones of the middle ear (malleus, incus, and stapes) receive the vibrations and multiply them 20 times. The stapes strikes the oval window causing it to vibrate. This vibration is passed to the fluid of the cochlea. The hair cells in the cochlea respond to the changes in pressure and send a message to the sensory neurones of the auditory nerve, which carries the message to the brain.

8 Vision begins as light is received by the photoreceptor cells (rods and cones). These synapse with their own bipolar neurones. Each bipolar cell synapses with a ganglion cell. The axons of the ganglion cells make up the optic nerve that carries the message of vision to the brain.

9 A stimulus is a change in the environment (internal or external) that is detected by a receptor and elicits a response. A reflex is a rapid, unconscious response.

10 Sensory receptors include:

- mechanoreceptors, which are sensitive to pressure (e.g. the hair cells of the cochlea)
- chemoreceptors, which respond to chemical substances (e.g. taste buds)
- thermoreceptors, which respond to change in temperature (e.g. nerve endings in the skin)
- photoreceptors, which respond to light energy (e.g. rods and cones in the eye).

11 During the pain reflex, pressure receptors generate a nerve impulse in a sensory neurone that carries the impulse to the spinal cord. In the spinal cord, a relay neurone connects with the motor neurone. The motor neurone carries the impulse to the muscle (effector), which contracts and so withdraws from the painful stimulus.

12 Innate behaviour develops independently of environmental context. Two types of innate behaviour in invertebrates are taxis and kinesis. The movement of the flatworm *Planaria* towards food is an example of chemotaxis. An example of kinesis can be seen with woodlice, which move about less in optimum (humid) conditions and more in unfavourable (dry) conditions.

13 Learned behaviour develops as a result of experience. Learning can improve the chances of survival. Imprinting in ducklings ensures that they stay close to their mother. Newly hatched male songbirds have a species-specific song that is inherited (crude template) but they can also learn to improve the song that they have inherited. First, during the first 100 days of their life, the young males memorize the song of nearby adults of the same species and modify their inherited template. Second, during the motor phase, they practise singing the song they have heard from the adults. When the male is sexually mature, his song will help him find a mate.

14 Classical conditioning can be used to modify a reflex response, as shown in Pavlov's experiment with dogs. Salivation in dogs is a reflex response to food. The unconditioned stimulus (UCS) of food elicits the unconditioned reflex (UCR) of salivation. Pavlov rang a bell (a neutral stimulus, NS) just before a dog tasted food. After training, Pavlov could ring the bell (a conditioned stimulus, CS) and the dog would salivate (a conditioned reflex, CR) in response to the bell alone. The dog had learned to respond to the NS.

15 Presynaptic neurones can either excite or inhibit postsynaptic transmission. Neurones are on the receiving end of many excitatory and inhibitory stimuli. Decision making in the central nervous system (CNS) occurs when the sum of one type of stimuli is greater than the sum of another type of stimuli. For example, if the sum of excitatory stimuli is greater, the axon will fire.

16 Excitatory neurotransmitters diffuse into the synapse and increase the permeability of the postsynaptic membrane to the sodium ion (Na^+). The influx of sodium depolarizes the neurone in a wave from one adjacent area to another, resulting in an action potential. This is how an impulse is carried along a nerve. Inhibitory neurotransmitters have the opposite effect by causing potassium ions (K^+) to move out of the postsynaptic membrane.

17 Psychoactive drugs affect mood and behaviour. Three excitatory drugs are nicotine, cocaine, and amphetamines. Three inhibitory drugs are benzodiazepine, alcohol, and tetrahydrocannabinol (THC). Excitatory drugs can increase postsynaptic transmission. For example, cocaine excites the postsynaptic neurons, causing them to produce dopamine in the synapses of the brain. Dopamine stimulates the pleasure centre in the brain. This results in euphoria and talkativeness, and sometimes violent behaviour. The inhibitory drug THC binds to receptors in the cerebellum and reduces coordination. It produces a mellow and relaxed mood.

18 The effect of slow-acting neurotransmitters (NT) on neurones enables memory and learning. Using the giant marine snail *Aplysia*, Eric Kandel discovered that a slow-acting NT causes an influx of Ca^{2+} into the presynaptic neurone. This causes the production of cyclic AMP (cAMP), which then activates protein kinase (PKA). PKA enhances release of the NT from the presynaptic neurone, which results in short-term learning. For memory to be created, an increased level of PKA reaches the nucleus and results in genes making proteins.

19 Animal behaviour is a complicated series of responses to the environment in which the animal lives. Some populations of animals have changed their responses to the environment so drastically that new species have been formed.

20 Natural selection can change the frequency of observed animal behaviour. Behaviour that increases the chances of survival and reproduction will become more common. Innate behaviour spreads more slowly through a population than learned behaviour.

Chapter 13, Option B: Biotechnology and bioinformatics

1 Microorganisms are metabolically diverse. This means that they have diverse sources of carbon, which they use to build other molecules. Four types of metabolism exhibited by microorganisms are:

- photoautotrophism, these organisms, e.g. algae, use sunlight for energy and CO_2 as a carbon source
- photoheterotrophism, these organisms, e.g. purple bacteria, can use light energy but must get their carbon from an organic compound
- chemoautotrophism, these organisms, e.g. sulfur bacteria that use H_2S for energy, use inorganic compounds for energy and CO_2 as their carbon source
- chemoheterotrophism, these organisms, e.g. protozoa, bacteria, and all fungi, use preformed organic compounds as an energy source and a carbon source.

2 Pathway or metabolic engineering is the practice of optimizing genetic and regulatory processes within microorganisms. The purpose of controlling the genes of a microorganism and regulating its biochemical pathways is to increase the production of a substance (a product that we desire) by the cell. The French company Sanofi has begun brewing Baker's yeast that can make a malaria drug on an industrial scale. It will begin producing 70 million doses a year. This breakthrough was published in the journal *Nature* in April 2013.

3 Industrial microbiology is now growing microorganisms on a large scale to produce commercially valuable products such as penicillin. This process is referred to as fermentation. Currently, antibiotics are the most important product of fermentation; biogas and citric acid are other important products of fermentation.

4 Genetically modified (GM) crops are plants that have been genetically modified by introducing a new gene that does not normally occur in the species. When genes are expressed, the result is a protein or series of proteins. Genetically modified plants have been given new genes so that new proteins are made. An example is the development of herbicide-resistant soybeans. Using a bacterium that naturally infects plants as a vector, a herbicide-resistant gene has been introduced into soybeans. The resulting GM soybean crop should have more yield because competing weeds can be killed with a herbicide that will not affect the soybean.

5 In order to produce genetically modified (GM) plants, methods have had to be developed to deliver a transgene without damaging the plant cell. A transgene is a gene that is transferred from one organism to another. After introducing the gene, the plant cell must be able to reproduce an entire plant. The three methods used currently are: electroporation, microinjection, and biolistics.

6 If you want to retrieve the DNA sequence of a target gene, e.g. the gene that makes soybeans resistant to glyphosate, you can go to a database such as GenBank and find the gene you are looking for.

7 The gene you are looking for in the database will be an open reading frame (ORF). An ORF is a length of DNA that has a start code of ATG and does not exhibit any of the stop codes (TAA, TAG, TGA).

8 *Agrobacterium tumifaciens* is a bacterium that can be used to introduce genes into many different plants. It carries the gene to make the new product in its plasmid. When it infects the cells of a plant, the plant cells take up the plasmid and carry the genes to the chromosome in the nucleus or to the DNA in the chloroplast.

9 Recombinant DNA can be placed into plants using various methods, including the following examples.

- Leaf discs. For example, discs removed from tobacco plants are incubated with genetically engineered *Agrobacter* for 24 hours. Eventually the plant cells acquire the DNA from the bacteria.
- Whole plants. Plants can be submerged in a bacterial solution containing a modified plasmid. A vacuum is applied to help force the bacterial solution into the air spaces between the plant cells. *Agrobacter* will move the plasmid into many of the plant cells.
- Protoplasts, using microinjection or biolistics.

10 Bioremediation is the use of an organism's metabolism to break down pollutants. Many microorganisms are used to decontaminate areas because they have the right enzymes that can break down the long chains of hydrocarbon molecules that are found in organic pollutants. The products produced after the breakdown are environmentally neutral.

- An example of the degradation of a hydrocarbon pollutant is the action of *Marinobacter* on benzene.
- *Pseudomonas* can be used to degrade the oil left after an oil spill.

11 Biofilms are cooperative aggregates of microorganisms that stick to surfaces as a glue-like material.

- These microorganisms can include many different types united together, such as fungi, bacteria, and algae.
- They hold themselves together by secreting extracellular polymeric substances (EPS) that stick to surfaces like glue.
- They can develop in a short time, even in hours.

12 Biofilms possess emergent properties. Emergent properties can be defined as novel and coherent structures, properties, and patterns arising during the self-organization of a complex system. In a biofilm the properties of the biofilm community are greater than the properties of the individual components. The emergent properties of biofilms include:

- a complex architecture
- quorum sensing
- resistance to antimicrobials.

13 As these colonies of bacteria become more dense, they can coordinate the expression of their genes in response to the density of their population. They accomplish this in the following manner.

- The first few bacteria make signalling molecules called inducers.
- Other bacteria have receptors that receive the signal of the inducer. The bacteria that receive the first message then make even more inducer.
- Soon the quantity of inducer in the population is high. This stimulates the bacteria in the population to transcribe their genes all at the same time.
- A very strong biofilm of cells and matrix is made as a result of all the cells working together.

14 A trickle filter is a biofilm of aerobic bacteria attached to the surface of filter media. Waste water trickles over the filter media and the attached aerobic bacteria oxidize the organic matter in the waste. The media used currently are plastic particles with high surface areas.

15 A marker is a genetic variation in a DNA sequence that can be observed. If a person has sickle cell anaemia, the characteristic cells can be observed under a microscope. You can actually see the cells becoming sickle

shaped. However, if someone has a predisposition to skin cancer, you can only see the genetic marker by using biotechnology techniques.

16 The Human Genome Project discovered that the most human genetic variation occurs in just a very few small DNA sequences. Most of these genetic variations are called SNPs (snips). We can recognize SNPs when they express an abnormal protein that causes a disease, e.g. sickle cell anaemia. People with a normal SNP will not have sickle cell anaemia.

17 A DNA microarray is a collection of DNA probes attached to a solid surface. A small amount of blood or other source of DNA is collected and applied to a DNA microarray, which is also called a gene chip. The gene chip is 'spotted' in precise locations with single strands of thousands of short, single-stranded known DNA in a grid-like pattern. Each spot has multiple copies of a known gene. This technology allows scientists to see the expression of genes by looking at the messenger RNA that is transcribed by the gene.

18 Biopharming uses genetically modified plants and animals to produce proteins for therapeutic use. A variety of innovative technologies is now available that will allow us to use pharmaceuticals derived from genetically engineered plants and animals to treat disease. For example, animals such as goats are now making pharmaceutical proteins for us along with their milk. Haemophiliacs lack a functional clotting protein called antithrombin III. Transgenic goats now produce this protein.

19 Viral vectors are a tool commonly used by molecular biologists to deliver new genetic material into cells. In 2011, a case of haemophilia B, caused by the absence of a coagulation factor, was treated successfully. A virus called AAV8 delivered the missing gene. So far six patients have begun to produce the factor again.

20 Bioinformatics is a field that uses both computer science and information technology to help us understand biological processes. The most data-rich area of bioinformatics is genomics. The Human Genome Project has given us much of the genomics for the human genome. It was completed in 2003 and is a map of the entire human genome, with all of the bases (ATGC) placed in the proper order and all of the genes located on the correct chromosome.

21 As the volume of biological data grows, so do the number and types of databases. Three major databases are:

- Swiss-Prot, a well curated database of protein sequences
- Ensembl, a database and browser of genomic information about humans and other vertebrates that can be used to explore Chromosome 21
- GenBank, a National Institutes of Health genetic sequence database that is an annotated collection of all publicly available DNA sequences.

22 GenBank is the largest public database of DNA sequences. BLAST is the software used to search the database GenBank:

- a scientist clones a gene
- the scientist enters the sequence of the gene into GenBank
- GenBank searches the sequence of the gene against other sequences to see if there is a match
- the result gives the scientist information about what organisms have the same gene, the name of the gene, and the function of the gene.

23 BLAST is an acronym for Basic Local Alignment Search Tool. It searches the database GenBank for local alignments. Local alignments can detect small regions of similarity that may be more biologically significant. Reasons to align are to find:

- a functional relationship, e.g. the genes for leptin have the same function in a mouse and a human
- a structural relationship, e.g. if a scientist has isolated a protein but does not know what its function is, it can be structurally aligned in a database with another protein and the function may be learned
- an evolutionary relationship, to indicate common ancestors and show phylogenetic relationships.

24 BLASTn (nucleotide BLAST) aligns nucleotide sequences. BLASTp (protein BLAST) compares the sequence of a protein by aligning the sequences of amino acids that make up the protein.

25 Gene function can be studied using a model organism. The mouse, *Mus musculus*, was used when looking at the leptin gene, which is conserved in humans and many other organisms. A database can be used for the comparison but another method that can be used to determine exactly what a gene does is to 'knock it out' and see what happens. The mouse is a common 'knockout' (KO) species. Researchers knocked out the leptin gene in mice by replacing it with a mutant gene, and found that the mice become obese.

Chapter 14, Option C: Ecology and conservation

1 Limiting factors affect the distribution of species in a community. The distribution of species depends on those factors, which are both abiotic (non-living) and biotic (living).

- Abiotic factors include light, atmosphere, water, temperature, and soil salinity.
- Biotic factors include living organisms and the interrelationships of those organisms.

2 Shelford's law of tolerance states that the levels of one or more chemical or physical factor(s) determines the abundance and distribution of a species in an ecosystem. When the factors fall below or rise above the levels tolerated by the species, the species will cease to exist in that ecosystem. For example, three species of kangaroos in Australia are distributed based on climate. A species of plant in California, the *Encelia*, is distributed based on water availability.

3 A keystone species is one that is not especially abundant but still exhibits strong control over the structure of a community. Community structure can be strongly affected by keystone species. The sea star on a coast of North America is necessary for the structure of that community. When it is removed from the intertidal area, a mussel is able to take over the rocky area and exclude algae and other invertebrates from that zone.

4 The concept of niche includes where an organism lives (its spatial habitat), what and how it eats (its feeding activities), and its interactions with other species. The niche is the role the organism plays in the community.

5 Symbiosis is a type of interaction of species within a community that results in mutual benefit. For example, *Zooxanthellae* are single-celled algae that live in the tissue of reef-building coral. The coral provides the compounds and the environment for photosynthesis for *Zooxanthellae.* In turn, the algae provide food for the coral. It gives the coral a boost of nutrients so that it can secrete the skeleton of calcium carbonate that it needs to build the reef.

6 Pyramids of energy show how much energy is left at each trophic level. In an ideal situation 10% of energy is transferred from one tropic level to the next. The percentage of ingested energy transferred to biomass is dependent on the respiration rate.

7 Pyramids of biomass are similar to pyramids of energy. Higher trophic levels have lower biomass. Biomass is lost during respiration at each trophic level.

8 The feed conversion ratio (FCR) is a measure of the efficiency of an animal's ability to convert feed mass into increased body mass. It is expressed as a ratio:

$$\frac{\text{mass of food eaten}}{\text{body mass gain}}$$

For example:

$$\frac{\text{8 kg of food}}{\text{1 kg of weight gain}} = 8$$

This is a high FCR value. Animals with low FCRs use food efficiently.

9 Ecological succession will occur until it finally develops enough complexity to become a stable community. The type of stable community that will emerge in an area is predicted by climate. This predicted ecosystem is called the climax community. For example, at the Indiana Dunes (USA) the climax community is a temperate forest.

10 Closed systems exchange energy but not matter. No natural system on Earth is considered to be closed but the entire planet can be considered 'almost' closed.

11 A disturbance is a new environmental condition that affects the structure and rate of change in an ecosystem. Examples of disturbance can be natural (fire, flood, wind, or insect invasion) or artificial (clearing a forest, building a road, ploughing a field, or clearing a natural area to build a housing development). Intermediate levels of disturbances, such as fires every few years, are the most effective in maintaining diversity.

12 Biological control is the use of a natural predator to control unwanted or invasive species. However, there is always a risk associated with introducing a new organism into an ecosystem. Unexpected consequences may occur, such as the population explosion of cane toads in Australia.

13 The principle of competitive exclusion states that no two species can occupy the same niche. When two species have a similar need for the same resources, such as food, one will be excluded. The example of the cane toad illustrates that, as a result of competitive exclusion and the absence of predators, an introduced alien species can become invasive.

14 Biomagnification is a process by which chemical substances become more concentrated at each trophic level. DDT, which was used to control mosquitoes and other insect pests, does not break down quickly and has persisted for decades in the environment. It becomes more and more concentrated in animal tissue as it moves up the food chain. It caused a significant decline in the number of predatory birds and was banned in the USA in 1971.

15 Macroplastic items, such as plastic bottles, bags, nets, and fishing line, can pose a serious threat to marine wildlife. Microplastics are plastic particles smaller than 5 mm; they are produced directly as abrasives and exfoliants, or indirectly as a consequence of the breakdown of larger sized plastic materials. The PCBs and other persistent organic pollutants (POPs) adsorbed onto the plastic pieces build up in the body of fish and become magnified as smaller fish are eaten by larger fish.

16 Indicator species are very sensitive to environmental change, just as canaries are to air quality in a coal mine. A biotic index can be calculated for a stream using indicator species. If the stream has a high number of organisms sensitive to pollution, this will result in a high biotic index. The higher the biotic index, the better the water quality.

17 *In situ* conservation of species takes place in nature reserves or national parks. *Ex situ* is the preservation of species outside their natural habitat. There are three methods of *ex situ* preservation: the captive breeding of animals, the cultivation of plants in botanic gardens, and the storing of seeds in seed banks. Captive breeding has rescued the Mexican gray wolf from extinction.

18 Three biogeographic factors influence species diversity.

- The latitude gradient explains the effect of climate on species diversity. The farther away from the equator, the more the number of species declines.
- The area effect explains the effect of geographic area on species richness. The larger the geographic area, the more species it can support. Larger areas offer a greater diversity of habitats than a smaller area.
- The elevation gradient explains the effect of altitude on species richness. At higher altitudes, species richness increases up to a point. That point is about half way up the elevation and is called the mid-point bulge. At the mid-point bulge the diversity is the greatest. After the mid-point bulge species diversity declines.

19 Biological diversity can be described in two separate ways: evenness and richness. The number of different organisms in a particular area is richness. Evenness is how the quantity of each different organism compares with the other. The Simpson diversity index takes both of these into account.

20 The Simpson diversity index is calculated using the formula:

$$\frac{D = N(N-1)}{\text{sum of } n(n-1)}$$

where

D = diversity index
N = total number of organisms of all species found in an ecosystem
n = number of individuals of a particular species.

21 Change in population density =
(nationality + immigration)
minus
(mortality + emigration)

22 Four types of factor that influence change in the sigmoid growth curve are:

- abiotic factors, e.g. temperature
- biotic factors, e.g. cane toads
- density-independent factors, e.g. freezing
- density-dependent factors, e.g. disease.

23 Soil that is waterlogged is so saturated with water that oxygen cannot get into the soil. Healthy plant roots need oxygen. Waterlogged soils create anaerobic soil conditions with no oxygen. Anaerobic conditions facilitate the growth of denitrifying bacteria, which convert the nitrates needed by plants back to gaseous nitrogen. Waterlogged soils become nitrate depleted.

24 Phosphorous is not very abundant in the biosphere and does not include a substantial atmospheric pool like carbon and nitrogen. The largest quantity of phosphorous is in marine sediments and mineral deposits

25 Currently, the major use of phosphate is in chemical fertilizer, which is used in modern agricultural production. Phosphorous being mined for fertilizer is consuming the phosphorus more quickly than geological cycles can replace it.

Chapter 15, Option D: Human physiology

1 Some nutrients must be a part of a person's diet because these nutrients are required but they cannot be synthesized from other molecules. These substances are called essential nutrients.

2 Essential nutrients include minerals and some vitamins, fatty acids, and amino acids. Long-term deprivation of any of these essential nutrients leads to a deficiency disease.

3 Overweight individuals are more prone to hypertension (high blood pressure) and type II diabetes.

4 Digestion requires the addition of secretions necessary for chemical digestion into the stomach (gastric secretions) and into the small intestine. The stomach has cells within 'pits' that provide gastric juice and the small intestine receives secretions from the pancreas and liver.

5 Hormonal feedback mechanisms and the autonomic nervous system control when and how much of these digestive secretions are produced.

6 Ulcer(s) of the stomach are now known to be linked to the presence of bacteria growing in the stomach below the protective mucus layer. This bacteria species is *Helicobacter pylori*.

7 The 'capillaries' of the liver are called sinusoids. Each sinusoid receives a mix of blood from both the hepatic artery and hepatic portal vein. Sinusoids are more porous than typical capillaries and are lined with a type of leucocyte called Kupffer cells.

8 Liver cells (hepatocytes) help recycle the components of erythrocytes (including haemoglobin). Most red blood cells have a cellular life span of around 120 days. Many millions of erythrocytes must be recycled each day.

9 The liver has many other functions, including removal of toxins from blood, storage of iron and some vitamins, production of some blood proteins, and storage of an energy reserve known as glycogen.

10 The function of heart valves is to keep blood flowing in a single direction within all blood vessels. Blood flow from the right side of the heart is called the pulmonary circulation; blood flow from the left side is called the systemic circulation. The pumping of blood and the action of heart valves is synchronous between the right and left sides of the heart.

11 When one is 'at rest', the heart controls its own pace by impulses initiated by a group of cells located in the right atrium known as the sinoatrial (SA) node. The SA node results in atrial systole and, after a short delay, the impulse is also relayed to the ventricles for their systole by way of another group of cells known as the atrioventricular (AV) node.

12 Body activity (exercise) leads to an increase in carbon dioxide in the bloodstream. This leads to a decrease in pH of the blood. The lowered pH is sensed by receptors that respond in a way to cause the medulla oblongata of the brainstem to send impulses to the SA node to increase heart rate.

13 Haemoglobin is a relatively large and complex protein designed to carry respiratory gases, especially oxygen. When haemoglobin is temporarily bonded to one or more oxygen molecules, the haemoglobin changes its molecular shape to have a greater affinity for more oxygen molecules. As haemoglobin can carry a maximum of four oxygen molecules, the form of haemoglobin with the highest affinity for oxygen is one that is currently carrying three oxygen molecules.

14 Oxygen dissociation curves can illustrate the differing affinities for oxygen shown by different types of haemoglobin or by any one haemoglobin type in a variety of environmental situations.

15 Even though haemoglobin is capable of transporting carbon dioxide molecules in the blood, most carbon dioxide is transported in the form of hydrogen carbonate ions. It is this conversion of carbon dioxide to hydrogen carbonate ions that lowers the pH of blood as more and more carbon dioxide is produced by the body during exercise.