Diploma Programme Course Outline

Name of the DP subject	Biology (HL/SL)
Level	**Higher ☐** **Standard ☐** **SL and HL students are taught the core components in the same class**

YEAR 1

THEMES/TOPICS	**TOPIC/CONCEPT**	**ASSESSMENT COMPONENTS**
A Unity and Diversity **- Biomolecules** • **Water Structure** • **Hydrogen Bonds** • **Cohesive Properties** • **Solvent properties** • **Physical properties**	**A1.1.1 Water as a medium for life** Students should appreciate that the first cells originated in water and that water remains the medium in which most processes of life occur **A1.1.2 Hydrogen Bonds** Students should understand that polarity of covalent bonding within water molecules is due to unequal sharing of electrons and that hydrogen bonding due to this polarity occurs between water molecules. Students should be able to represent two or more water molecules and hydrogen bonds between them with the notation shown below to indicate polarity. **A1.1.3 Cohesive Properties** Cohesion of water molecules due to hydrogen bonding and consequences for organisms Include transport of water under tension in xylem and the use of water surfaces as habitats due to the effect known as surface tension. **A1.1.4 Adhesion**	Paper 1 assessment Paper 2 assessment AO1 AO 2

	Adhesion of water to materials that are polar or charged and impacts for organisms Include capillary action in soil and in plant cell walls. **A1.1.5 Solvent properties** Solvent properties of water linked to its role as a medium for metabolism and for transport in plants and animals Emphasize that a wide variety of hydrophilic molecules dissolve in water and that most enzymes catalyse reactions in aqueous solution. Students should also understand that the functions of some molecules in cells depend on them being hydrophobic and insoluble. **A1.1.6 Physical properties of water** Physical properties of water and the consequences for animals in aquatic habitats Include buoyancy, viscosity, thermal conductivity and specific heat capacity. Contrast the physical properties of water with those of air and illustrate the consequences using examples of animals that live in water and in air or on land, such as the black-throated loon *(Gavia arctica)* and the ringed seal *(Pusa hispida)*	
Higher Level **A1.1.7 Origins of water**	**A1.1.7** ➢ Extraplanetary origin of water on Earth and reasons for its retention	Paper 1 assessment Paper 2 assessment AO1 AO 2

	➢ The abundance of water over billions of years of Earth's history has allowed life to evolve. Limit hypotheses for the origin of water on Earth to asteroids and reasons for retention to gravity and temperatures low enough to condense water. **A1.1.8** ➢ Relationship between the search for extraterrestrial life and the presence of water ➢ Include the idea of the "Goldilocks zone".	**AO3**
B1 Organic Compounds	**B1.1.1** Chemical properties of Carbon atom Chemical properties of a carbon atom allowing for the formation of diverse compounds upon which life is based Students should understand the nature of a covalent bond. Students should also understand that a carbon atom can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements. Include among the diversity of carbon compounds examples of molecules with branched or unbranched chains and single or multiple rings. NOS: Students should understand that scientific conventions are based on international agreement (SI metric unit prefixes "kilo", "centi", "milli", "micro" and "nano"). **B1.1.2 Production of macromolecules** Production of macromolecules by condensation reactions that link monomers to form a polymer	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

	Students should be familiar with examples of polysaccharides, polypeptides and nucleic acids. **B1.1.3 Digestion of polymers into monomers** Digestion of polymers into monomers by hydrolysis reactions Water molecules are split to provide the -H and -OH groups that are incorporated to produce monomers, hence the name of this type of reaction.	

A1.2.1 **Nucleic Acids**	**A1.2.1** ➢ DNA as the genetic material of all living organisms ➢ Some viruses use RNA as their genetic material but viruses are not considered to be living. **A1.2.2** ➢ Components of a nucleotide ➢ In diagrams of nucleotides use circles, pentagons and rectangles to represent relative positions of phosphates, pentose sugars and bases. **A1.2.3** ➢ Sugar–phosphate bonding and the sugar–phosphate “backbone” of DNA and RNA ➢ Sugar–phosphate bonding makes a continuous chain of covalently bonded atoms in each strand of DNA or RNA nucleotides, which forms a strong “backbone” in the molecule. **A1.2.4** ➢ Bases in each nucleic acid that form the basis of a code ➢ Students should know the names of the nitrogenous bases. **A1.2.5** ➢ RNA as a polymer formed by condensation of nucleotide monomers ➢ Students should be able to draw and recognize diagrams of the structure of single nucleotides and RNA polymers. **A1.2.6** ➢ DNA as a double helix made of two antiparallel strands of nucleotides with two strands linked by hydrogen bonding between complementary base pairs	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ In diagrams of DNA structure, students should draw the two strands antiparallel, but are not required to draw the helical shape. Students should show adenine (A) paired with thymine (T), and guanine (G) paired with cytosine (C). Students are not required to memorize the relative lengths of the purine and pyrimidine bases, or the numbers of hydrogen bonds. **A1.2.7** ➢ Differences between DNA and RNA ➢ Include the number of strands present, the types of nitrogenous bases and the type of pentose sugar. Students should be able to sketch the difference between ribose and deoxyribose. Students should be familiar with examples of nucleic acids. **A1.2.8** ➢ Role of complementary base pairing in allowing genetic information to be replicated and expressed ➢ Students should understand that complementarity is based on hydrogen bonding. **A1.2.9** ➢ Diversity of possible DNA base sequences and the limitless capacity of DNA for storing information ➢ Explain that diversity by any length of DNA molecule and any base sequence is possible. Emphasize the enormous capacity of DNA for storing data with great economy. **A1.2.10** ➢ Conservation of the genetic code across all life forms as evidence of universal common ancestry ➢ Students are not required to memorize any specific examples.	

Higher Level A1.2.11 Directionality of RNA and DNA • **Genetic Materials** • **Base Pairing** • **Directionality** • **Nucleosomes**	**A1.2.11** ➢ Directionality of RNA and DNA ➢ Include 5' to 3' linkages in the sugar–phosphate backbone and their significance for replication, transcription and translation. **A1.2.12** ➢ Purine-to-pyrimidine bonding as a component of DNA helix stability ➢ Adenine–thymine (A–T) and cytosine–guanine (C–G) pairs have equal length, so the DNA helix has the same three-dimensional structure, regardless of the base sequence. **A1.2.13** ➢ Structure of a nucleosome ➢ Limit to a DNA molecule wrapped around a core of eight histone proteins held together by an additional histone protein attached to linker DNA. AOS: Students are required to use molecular visualization software to study the association between the proteins and DNA within a nucleosome. **A1.2.14** ➢ Evidence from the Hershey–Chase experiment for DNA as the genetic material	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Students should understand how the results of the experiment support the conclusion that DNA is the genetic material. ➢ NOS: Students should appreciate that technological developments can open up new possibilities for experiments. When radioisotopes were made available to scientists as research tools, the Hershey–Chase experiment became possible. **A1.2.15** ➢ Chargaff's data on the relative amounts of pyrimidine and purine bases across diverse life forms ➢ NOS: Students should understand how the "problem of induction" is addressed by the "certainty of falsification". In this case, Chargaff's data falsified the tetranucleotide hypothesis that there was a repeating sequence of the four bases in DNA.	
B1.1.2 Carbohydrates	**B1.1.2** ➢ Production of macromolecules by condensation reactions that link monomers to form a polymer ➢ Students should be familiar with examples of polysaccharides, polypeptides and nucleic acids.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4** **Formative** Tests Quizzes

	B1.1.4 ➢ Form and function of monosaccharides ➢ Students should be able to recognize pentoses and hexoses as monosaccharides from molecular diagrams showing them in the ring forms. Use glucose as an example of the link between the properties of a monosaccharide and how it is used, emphasizing solubility, transportability, chemical stability and the yield of energy from oxidation as properties. **B1.1.5** ➢ Polysaccharides as energy storage compounds ➢ Include the compact nature of starch in plants and glycogen in animals due to coiling and branching during polymerization, the relative insolubility of these compounds due to large molecular size and the relative ease of adding or removing alpha-glucose monomers by condensation and hydrolysis to build or mobilize energy stores. **B1.1.6** ➢ Structure of cellulose related to its function as a structural polysaccharide in plants ➢ Include the alternating orientation of beta-glucose monomers, giving straight chains that can be grouped in bundles and cross-linked with hydrogen bonds. **B1.1.7** ➢ Role of glycoproteins in cell–cell recognition ➢ Include ABO antigens as an example.	Presentations Research Think Pair Square

B1.1.8 Lipids	**B1.1.8** ➢ Hydrophobic properties of lipids ➢ Lipids are substances in living organisms that dissolve in non-polar solvents but are only sparingly soluble in aqueous solvents. Lipids include fats, oils, waxes and steroids. **B1.1.9** ➢ Formation of triglycerides and phospholipids by condensation reactions ➢ One glycerol molecule can link three fatty acid molecules or two fatty acid molecules and one phosphate group. **B1.1.10** ➢ Difference between saturated, monounsaturated and polyunsaturated fatty acids ➢ Include the number of double carbon (C=C) bonds and how this affects melting point. Relate this to the prevalence of different types of fatty acids in oils and fats used for energy storage in plants and endotherms respectively. **B1.1.11** ➢ Triglycerides in adipose tissues for energy storage and thermal insulation ➢ Students should understand that the properties of triglycerides make them suited to long-term energy storage functions. Students should be able to relate the use of triglycerides as thermal insulators to body temperature and habitat. **B1.1.12** ➢ Formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions ➢ Students should use and understand the term “amphipathic”. **B1.1.13**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Ability of non-polar steroids to pass through the phospholipid bilayer ➢ Include oestradiol and testosterone as examples. Students should be able to identify compounds as steroids from molecular diagrams.	
Proteins	**B1.2.1** ➢ Generalized structure of an amino acid ➢ Students should be able to draw a diagram of a generalized amino acid showing the alpha carbon atom with amine group, carboxyl group, R-group and hydrogen attached. **B1.2.2** ➢ Condensation reactions forming dipeptides and longer chains of amino acids ➢ Students should be able to write the word equation for this reaction and draw a generalized dipeptide after modelling the reaction with molecular models. **B1.2.3** ➢ Dietary requirements for amino acids ➢ Essential amino acids cannot be synthesized and must be obtained from food. Non-essential amino acids can be made from other amino acids. Students are not required to give examples of essential and non-essential amino acids. Vegan diets require attention to ensure essential amino acids are consumed. **B1.2.4**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	- Infinite variety of possible peptide chains - Include the ideas that 20 amino acids are coded for in the genetic code, that peptide chains can have any number of amino acids, from a few to thousands, and that amino acids can be in any order. Students should be familiar with examples of polypeptides. **B1.2.5** - Effect of pH and temperature on protein structure - Include the term “denaturation”.	

• **Variable Groups** • **Protein Structure** • **Types of proteins**	**B1.2.6** ➢ Chemical diversity in the R-groups of amino acids as a basis for the immense diversity in protein form and function ➢ Students are not required to give specific examples of R-groups. However, students should understand that R-groups determine the properties of assembled polypeptides. Students should appreciate that R- groups are hydrophobic or hydrophilic and that hydrophilic R-groups are polar or charged, acidic or basic. **B1.2.7** ➢ Impact of primary structure on the conformation of proteins ➢ Students should understand that the sequence of amino acids and the precise position of each amino acid within a structure determines the three-dimensional shape of proteins. Proteins therefore have precise, predictable and repeatable structures, despite their complexity. **B1.2.8** ➢ Pleating and coiling of secondary structure of proteins ➢ Include hydrogen bonding in regular positions to stabilize alpha helices and beta-pleated sheets. **B1.2.9** ➢ Dependence of tertiary structure on hydrogen bonds, ionic bonds, disulfide covalent bonds and hydrophobic interactions ➢ Students are not required to name examples of amino acids that participate in these types of bonding, apart from pairs of cysteines forming disulfide bonds. Students should understand that amine and carboxyl groups in R-groups can become positively or negatively charged by binding or dissociation of hydrogen ions and that they can then participate in ionic bonding. **B1.2.10** ➢ Effect of polar and non-polar amino acids on tertiary structure of proteins ➢ In proteins that are soluble in water, hydrophobic amino acids are clustered in the core of globular proteins. Integral proteins have regions with hydrophobic amino acids, helping them to embed in membranes. **B1.2.11**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Quaternary structure of non-conjugated and conjugated proteins ➢ Include insulin and collagen as examples of non-conjugated proteins and haemoglobin as an example of a conjugated protein. NOS: Technology allows imaging of structures that would be impossible to observe with the unaided senses. For example, cryogenic electron microscopy has allowed imaging of single-protein molecules and their interactions with other molecules. **B1.2.12** ➢ Relationship of form and function in globular and fibrous proteins ➢ Students should know the difference in shape between globular and fibrous proteins and understand that their shapes make them suitable for specific functions. Use insulin and collagen to exemplify how form and function are related.	

THEMES/TOPICS	**TOPIC/CONCEPT**	**ASSESSMENT COMPONENTS**
Higher Level **A2.1 – Origins of Cells** • Abiogenesis • Organic Material • Miller-Urey • Genetic Origins • LUCA Evidence	**A2.1.1** ➢ Conditions on early Earth and the pre-biotic formation of carbon compounds ➢ Include the lack of free oxygen and therefore ozone, higher concentrations of carbon dioxide and methane, resulting in higher temperatures and ultraviolet light penetration. The conditions may have caused a variety of carbon compounds to form spontaneously by chemical processes that do not now occur.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

A2.1.2

- Cells as the smallest units of self-sustaining life
- Discuss the differences between something that is living and something that is non-living. Include reasons that viruses are considered to be non-living.

A2.1.3

- Challenge of explaining the spontaneous origin of cells
- Cells are highly complex structures that can currently only be produced by division of pre-existing cells. Students should be aware that catalysis, self-replication of molecules, self-assembly and the emergence of compartmentalization were necessary requirements for the evolution of the first cells.
  NOS: Students should appreciate that claims in science, including hypotheses and theories, must be testable. In some cases, scientists have to struggle with hypotheses that are difficult to test. In this case the exact conditions on pre-biotic Earth cannot be replicated and the first protocells did not fossilize.

A2.1.4

- Evidence for the origin of carbon compounds
- Evaluate the Miller–Urey experiment.

A2.1.5

- Spontaneous formation of vesicles by coalescence of fatty acids into spherical bilayers
- Formation of a membrane-bound compartment is needed to allow internal chemistry to become different from that outside the compartment.

A2.1.6

- RNA as a presumed first genetic material
- RNA can be replicated and has some catalytic activity so it may have acted initially as both the genetic material and the enzymes of the earliest cells. Ribozymes in the ribosome are still used to catalyse peptide bond formation during protein synthesis.

	A2.1.7 ➢ Evidence for a last universal common ancestor ➢ Include the universal genetic code and shared genes across all organisms. Include the likelihood of other forms of life having evolved but becoming extinct due to competition from the last universal common ancestor (LUCA) and descendants of LUCA. **A2.1.8** ➢ Approaches used to estimate dates of the first living cells and the last universal common ancestor ➢ Students should develop an appreciation of the immense length of time over which life has been evolving on Earth. **A2.1.9** ➢ Evidence for the evolution of the last universal common ancestor in the vicinity of hydrothermal vents ➢ Include fossilized evidence of life from ancient seafloor hydrothermal vent precipitates and evidence of conserved sequences from genomic analysis.	

A2. **Introduction to cells** • Life functions • Cell theory • Cell Structure • Microscopes • Microscopes	**A2.2.1** ➢ Cells as the basic structural unit of all living organisms ➢ NOS: Students should be aware that deductive reason can be used to generate predictions from theories. Based on cell theory, a newly discovered organism can be predicted to consist of one or more cells. **A2.2.2** ➢ Microscopy skills ➢ AOS: Students should have experience of making temporary mounts of cells and tissues, staining, measuring sizes using an eyepiece graticule, focusing with coarse and fine adjustments, calculating actual size and magnification, producing a scale bar and taking photographs. NOS: Students should appreciate that measurement using instruments is a form of quantitative observation. **A2.2.3** ➢ Developments in microscopy ➢ Include the advantages of electron microscopy, freeze fracture, cryogenic electron microscopy, and the use of fluorescent stains and immunofluorescence in light microscopy. **A2.2.4** ➢ Structures common to cells in all living organisms ➢ Typical cells have DNA as genetic material and a cytoplasm composed mainly of water, which is enclosed by a plasma membrane composed of lipids. Students should understand the reasons for these structures. **A2.2.7** ➢ Processes of life in unicellular organisms ➢ Include these functions: homeostasis, metabolism, nutrition, movement, excretion, growth, response to stimuli and reproduction. **A2.2.9**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4** **Formative** Tests Quizzes Presentations Research Think Pair Square

	➢ Atypical cell structure in eukaryotes ➢ Use numbers of nuclei to illustrate one type of atypical cell structure in aseptate fungal hyphae, skeletal muscle, red blood cells and phloem sieve tube elements	
Cell Types • **Prokaryotes** • **Eukaryotes** • **Organelles** • **Identifying cells** • **Drawing cells**	**A2.2.5** ➢ Prokaryote cell structure ➢ Include these cell components: cell wall, plasma membrane, cytoplasm, naked DNA in a loop and 70S ribosomes. The type of prokaryotic cell structure required is that of Gram-positive eubacteria such as *Bacillus* and *Staphylococcus*. Students should appreciate that prokaryote cell structure varies. However, students are not required to know details of the variations such as the lack of cell walls in phytoplasmas and mycoplasmas. **A2.2.6** ➢ Eukaryote cell structure ➢ Students should be familiar with features common to eukaryote cells: a plasma membrane enclosing a compartmentalized cytoplasm with 80S ribosomes; a nucleus with chromosomes made of DNA bound to histones, contained in a double membrane with pores; membrane-bound cytoplasmic organelles including mitochondria, endoplasmic reticulum, Golgi apparatus and a variety of vesicles or vacuoles including lysosomes; and a cytoskeleton of microtubule and microfilaments. **A2.2.8**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4** **Formative** Tests Quizzes Presentations Research Think Pair Square

	➢ Differences in eukaryotic cell structure between animals, fungi, and plants ➢ Include presence and composition of cell walls, differences in size and function of vacuoles, presence of chloroplasts and other plastids, and presence of centrioles, cilia and flagella. **A2.2.10** ➢ Cell types and cell structures viewed in light and electron micrographs ➢ AOS: Students should be able to identify cells in light or electron micrographs as prokaryote, plant or animal. In electron micrographs, students should be able to identify these structures: nucleoid region, prokaryotic cell wall, nucleus, mitochondrion, chloroplast, sap vacuole, Golgi apparatus, rough and smooth endoplasmic reticulum, chromosomes, ribosomes, cell wall, plasma membrane and microvilli. **A2.2.11** ➢ Drawing and annotation based on electron micrographs ➢ AOS: Students should be able to draw and annotate diagrams of organelles (nucleus, mitochondria, chloroplasts, sap vacuole, Golgi apparatus, rough and smooth endoplasmic reticulum and chromosomes) as well as other cell structures (cell wall, plasma membrane, secretory vesicles and microvilli) shown in electron micrographs. Students must include the functions in their annotations.	

Higher Level **A2.2.12** **Origin of eukaryotic cells by endosymbiosis**	**A2.2.12** ➢ Origin of eukaryotic cells by endosymbiosis ➢ Evidence suggests that all eukaryotes evolved from a common unicellular ancestor that had a nucleus and reproduced sexually. Mitochondria then evolved by endosymbiosis. In some eukaryotes, chloroplasts subsequently also had an endosymbiotic origin. Evidence should include the presence in mitochondria and chloroplasts of 70S ribosomes, naked circular DNA and the ability to replicate. NOS: Students should recognize that the strength of a theory comes from the observations the theory explains and the predictions it supports. A wide range of observations are accounted for by the theory of endosymbiosis. **A2.2.13** ➢ Cell differentiation as the process for developing specialized tissues in multicellular organisms ➢ Students should be aware that the basis for differentiation is different patterns of gene expression often triggered by changes in the environment. **A2.2.14** ➢ Evolution of multicellularity ➢ Students should be aware that multicellularity has evolved repeatedly. Many fungi and eukaryotic algae and all plants and animals are multicellular. Multicellularity has the advantages of allowing larger body size and cell specialization.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

A2.3 – Viruses • **Viruses** • **Viral life cycle** • **Viral origins** • **Viral evolution**	**A2.3.1** ➢ Structural features common to viruses ➢ Relatively few features are shared by all viruses: small, fixed size; nucleic acid (DNA or RNA) as genetic material; a capsid made of protein; no cytoplasm; and few or no enzymes. **A2.3.2** ➢ Diversity of structure in viruses ➢ Students should understand that viruses are highly diverse in their shape and structure. Genetic material may be RNA or DNA, which can be either single- or double-stranded. Some viruses are enveloped in host cell membrane and others are not enveloped. Virus examples include bacteriophage lambda, coronaviruses and HIV. **A2.3.3** ➢ Lytic cycle of a virus ➢ Students should appreciate that viruses rely on a host cell for energy supply, nutrition, protein synthesis and other life functions. Use bacteriophage lambda as an example of the phases in a lytic cycle. **A2.3.4** ➢ Lysogenic cycle of a virus ➢ Use bacteriophage lambda as an example. **A2.3.5** ➢ Evidence for several origins of viruses from other organisms ➢ The diversity of viruses suggests several possible origins. Viruses share an extreme form of obligate parasitism as a mode of existence, so the structural features that they have in common could be regarded as convergent evolution. The genetic code is shared between viruses and living organisms. **A2.3.6** ➢ Rapid evolution in viruses ➢ Include reasons for very rapid rates of evolution in some viruses. Use two examples of rapid evolution: evolution of influenza viruses and of HIV. Consider the consequences for treating diseases caused by rapidly evolving viruses.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

B2.2 – Organelles and Compartmentalisation • **Organelles** • **Compartments**	**B2.2.1** ➢ Organelles as discrete subunits of cells that are adapted to perform specific functions ➢ Students should understand that the cell wall, cytoskeleton and cytoplasm are not considered organelles, and that nuclei, vesicles, ribosomes and the plasma membrane are **B2.2.2** ➢ Advantage of the separation of the nucleus and cytoplasm into separate compartments ➢ Limit to separation of the activities of gene transcription and translation – post-transcriptional modification of mRNA can happen before the mRNA meets ribosomes in the cytoplasm. In prokaryotes this is not possible – mRNA may immediately meet ribosomes. **B2.2.3** ➢ Advantages of compartmentalization in the cytoplasm of cells ➢ Include concentration of metabolites and enzymes and the separation of incompatible biochemical processes. Include lysosomes and phagocytic vacuoles as examples.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

• **Mitochondrion** • **Chloroplast** • **Nucleus** • **Ribosomes** • **Golgi Complex** • **Vesicle**	**B2.2.4** ➢ Adaptations of the mitochondrion for production of ATP by aerobic cell respiration ➢ Include these adaptations: a double membrane with a small volume of intermembrane space, large surface area of cristae and compartmentalization of enzymes and substrates of the Krebs cycle in the matrix. **B2.2.5** ➢ Adaptations of the chloroplast for photosynthesis ➢ Include these adaptations: the large surface area of thylakoid membranes with photosystems, small volumes of fluid inside thylakoids, and compartmentalization of enzymes and substrates of the Calvin cycle in the stroma. **B2.2.6** ➢ Functional benefits of the double membrane of the nucleus ➢ Include the need for pores in the nuclear membrane and for the nucleus membrane to break into vesicles during mitosis and meiosis. **B2.2.7** ➢ Structure and function of free ribosomes and of the rough endoplasmic reticulum ➢ Contrast the synthesis by free ribosomes of proteins for retention in the cell with synthesis by membrane- bound ribosomes on the rough endoplasmic reticulum of proteins for transport within the cell and secretion. **B2.2.8** ➢ Structure and function of the Golgi apparatus ➢ Limit to the roles of the Golgi apparatus in processing and secretion of protein. **B2.2.9** ➢ Structure and function of vesicles in cells ➢ Include the role of clathrin in the formation of vesicles.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

B2.3.1 - **Specialisation** - **Stem cells** - **Differentiation** - **Cell size**	**B2.3.1** ➢ Production of unspecialised cells following fertilisation and their development into specialised cells by differentiation ➢ Students should understand the impact of gradients on gene expression within an early-stage embryo. **B2.3.2** ➢ Properties of stem cells ➢ Limit to the capacity of cells to divide endlessly and differentiate along different pathways. **B2.3.3** ➢ Location and function of stem cell niches in adult humans ➢ Limit to two example locations and the understanding that the stem cell niche can maintain the cells or promote their proliferation and development. Bone marrow and hair follicles are suitable examples. **B2.3.4** ➢ Differences between totipotent, pluripotent and multipoint stem cells	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **Formative** Tests Quizzes Presentations Research Think Pair Square

	➢ Students should appreciate that cells in early-stage animal embryos are totipotent but soon become pluripotent, whereas stem cells in adult tissue such as bone marrow are multipotent. **B2.3.5** ➢ Cell size as an aspect of specialisation ➢ Consider the range of cell sizes in humans including male and female gametes, red and white blood cells, neurons and striated muscle fibres. **B2.3.6** ➢ Surface area-to-volume ratios and constrains on cell size ➢ Students should understand the mathematical ratio between volume and surface area and that exchange of materials across a cell surface depends on its area whereas the need for exchange depends on cell volume. NOS: Students should recognise that models are simplified versions of complex systems. In this case, surface area-to-volume relationship can be modelled using cubes of different side lengths. Although the cubes have a simpler shape than real organisms, scale factors operate in the same way.	

• **SA:Vol Ratio** • **Pneumocytes** • **Muscles Fibres** • **Egg and Sperm**	**B2.3.7** ➢ Adaptations to increase surface area-to-volume ratios of cells ➢ Include flattening of cells, microvilli and invagination. Use erythrocytes and proximal convoluted tubule cells in the nephron as examples. **B2.3.8** ➢ Adaptations of type I and type II pneumocytes in alveoli ➢ Limit to extreme thinness to reduce distances for diffusion in type I pneumocytes and the presence of many secretory vesicles (lamellar bodies) in the cytoplasm that discharge surfactant to the alveolar lumen in type II pneumocytes. Alveolar epithelium is an example of a tissue where more than one cell type is present, because different adaptations are required for the overall function of the tissue. **B2.3.9** ➢ Adaptations of cardiac muscle cells and striated muscle fibres ➢ Include the presence of contractile myofibrils in both muscle types and hypotheses for these differences: branching (branched or unbranched), and length and numbers of nuclei. Also include a discussion of whether a striated muscle fibre is a cell. **B2.3.10** ➢ Adaptations of sperm and egg cells ➢ Limit to gametes in humans.	Paper 1 assessment Paper 2 assessment AO1 AO 2
B2.1.1 **Cell membranes** **Phospholipids** **Membrane Proteins** **Glycosylation** **Fluid-Mosaic Model**	**B2.1.1** ➢ Lipid bilayers as the basis of cell membranes ➢ Phospholipids and other amphipathic lipids naturally form continuous sheet-like bilayers in water. **B2.1.2**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Lipid bilayers as barriers ➢ Students should understand that the hydrophobic hydrocarbon chains that form the core of a membrane have low permeability to large molecules and hydrophilic particles, including ions and polar molecules, so membranes function as effective barriers between aqueous solutions. **B2.1.4** ➢ Integral and peripheral proteins in membranes ➢ Emphasise that membrane proteins have diverse structures, locations and functions. Integral proteins are embedded in one or both of the lipid layers of a membrane. Peripheral proteins are attached to one or other surface of the bilayer. **B2.1.9** ➢ Structure and function of glycoproteins and glycolipids ➢ Limit to carbohydrate structures linked to proteins or lipids in membranes, location of carbohydrates on the extracellular side of the membranes, and roles in cell adhesion and cell recognition. **B2.1.10** ➢ Fluid mosaic model of membrane structure ➢ Students should be able to draw a two-dimensional representation of the model and include peripheral and integral proteins, glycoproteins, phospholipids and cholesterol. Indicate hydrophobic and hydrophilic regions.	**Formative** Tests Quizzes Presentations Research Think Pair Square

	B1.1.12 Formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions Students should use and understand the term “amphipathic”.	

B1.1.13 **Membrane Transport** **Simple diffusion** **Facilitated Diffusion** **Active Transport**	**B1.1.13** ➢ Ability of non-polar steroids to pass through the phospholipid bilayer ➢ Include oestradiol and testosterone as examples. Students should be able to identify compounds as steroids from molecular diagrams. **B2.1.3** ➢ Simple diffusion across membranes ➢ Use movement of oxygen and carbon dioxide molecules between phospholipids as examples of simple diffusion across membranes. **B2.1.5** ➢ Movement of water molecules across membranes by osmosis and the role of aquaporins ➢ Include an explanation in terms of random movement of particles, impermeability of membranes to solutes and differences in solute concentration. **B2.1.6** ➢ Channel proteins for facilitated diffusion ➢ Students should understand how the structure of channel proteins makes membranes selectively permeable by allowing specific ions to diffuse through when channels are open but not when they are closed. **B2.1.7** ➢ Pump proteins for active transport ➢ Students should appreciate that pumps use energy from ATP to transfer specific particles across membranes and therefore that they can move particles against a concentration gradient. **B2.1.8** ➢ Selectivity in membrane permeability	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4** **Formative** Tests Quizzes Presentations Research Think Pair Square IA

	➢ Facilitated diffusion and active transport allow selective permeability in membranes. Permeability by simple diffusion is not selective and depends only on the size and hydrophilic or hydrophobic properties of particles. **D2.3.2** ➢ Water movement from less concentrated to more concentrated solutions ➢ Students should express the direction of movement in terms of solute concentration, not water concentration. Students should use the terms “hypertonic”, “hypotonic” and “isotonic” to compare concentration of solutions. **D2.3.3** ➢ Water movement by osmosis into or out of cells ➢ Students should be able to predict the direction of net movement of water if the environment of a cell is hypotonic or hypertonic. They should understand that in an isotonic environment there is dynamic equilibrium rather than no movement of water. **D2.3.4** ➢ Changes due to water movement in plant tissue bathed in hypotonic and hypertonic solutions ➢ AOS: Students should be able to measure changes in tissue length and mass, and analyse data to deduce isotonic solute concentration. Students should also be able to use standard deviation and standard error to help in the analysis of data. Students are not required to memorise formulae for calculating these statistics. Standard deviation and standard error could be determined for the results of this experiment if there are repeats for each concentration. This would allow the reliability of length and mass measurements to be compared. Standard error could be shown graphically as error bars. **D2.3.5** ➢ Effects of water movement on cells with a cell wall	

	➢ Include the development of turgor pressure in a hypotonic medium and plasmolysis in a hypertonic medium. **D2.3.6** ➢ Effects of water movement on cells that lack a cell wall ➢ Include swelling and bursting in a hypotonic medium, and shrinkage and crenation in a hypertonic medium. Also include the need for removal of water by contractile vacuoles in freshwater unicellular organisms and the need to maintain isotonic tissue fluid in multicellular organisms to prevent harmful changes. **D2.3.7** ➢ Medical applications of isotonic solutions ➢ Include intravenous fluids given as part of medical treatment and bathing of organs ready for transplantation as examples	
C1.1.1 • **Enzymes** • **Metabolism** • **Enzymes** • **Specificity** • **Enzymes Activity** • **Enzymes Reactions**	**C1.1.1** ➢ Enzymes as catalysts ➢ Students should understand the benefit of increasing rates of reaction in cells. **C1.1.2** ➢ Role of enzymes in metabolism ➢ Students should understand that metabolism is the complex network of interdependent and interacting chemical reactions occurring in living organisms. Because of enzyme specificity, many different enzymes are required by living organisms, and control over metabolism can be exerted through these enzymes.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4** **Formative** Tests Quizzes Presentations Research

	C1.1.3 ➢ Anabolic and catabolic reactions ➢ Examples of anabolism should include the formation of macromolecules from monomers by condensation reactions including protein synthesis, glycogen formation and photosynthesis. Examples of catabolism should include hydrolysis of macromolecules into monomers in digestion and oxidation of substrates in respiration. **C1.1.4** ➢ Enzymes as globular proteins with an active site for catalysis ➢ Include that the active site is composed of a few amino acids only, but interactions between amino acids within the overall three-dimensional structure of the enzyme ensure that the active site has the necessary properties for catalysis. **C1.1.5** ➢ Interactions between substrate and active site to allow induced-fit binding ➢ Students should recognize that both substrate and enzymes change shape when binding occurs. **C1.1.6** ➢ Role of molecular motion and substrate-active site collisions in enzyme catalysis ➢ Movement is needed for a substrate molecule and an active site to come together. Sometimes large substrate molecules are immobilized while sometimes enzymes can be immobilized by being embedded in membranes.	Think Pair Square IA

	C1.1.7 ➢ Relationships between the structure of the active site, enzyme–substrate specificity and denaturation ➢ Students should be able to explain these relationships. **C1.1.8** ➢ Effects of temperature, pH and substrate concentration on the rate of enzyme activity ➢ The effects should be explained with reference to collision theory and denaturation. ➢ AOS: Students should be able to interpret graphs showing the effects. NOS: Students should be able to describe the relationship between variables as shown in graphs. They should recognize that generalized sketches of relationships are examples of models in biology. Models in the form of sketch graphs can be evaluated using results from enzyme experiments. **C1.1.9** ➢ Measurements in enzyme-catalysed reactions ➢ AOS: Students should determine reaction rates through experimentation and using secondary data. **C1.1.10** ➢ Effect of enzymes on activation energy ➢ AOS: Students should appreciate that energy is required to break bonds within the substrate and that there is an energy yield when bonds are made to form the products of an enzyme- catalysed reaction. Students should be able to interpret graphs showing this effect	

• **Metabolic Pathways** • **Energetics** • **Enzyme Inhibition** • **Feedback Inhibition** • **Irreversible Activity**	**C1.1.11** ➢ Intracellular and extracellular enzyme-catalysed reactions ➢ Include glycolysis and the Krebs cycle as intracellular examples and chemical digestion in the gut as an extracellular example. **C1.1.12** ➢ Generation of heat energy by the reactions of metabolism ➢ Include the idea that heat generation is inevitable because metabolic reactions are not 100% efficient in energy transfer. Mammals, birds and some other animals depend on this heat production for maintenance of constant body temperature. **C1.1.13** ➢ Cyclical and linear pathways in metabolism ➢ Use glycolysis, the Krebs cycle and the Calvin cycle as examples. **C1.1.14** ➢ Allosteric sites and non-competitive inhibition ➢ Students should appreciate that only specific substances can bind to an allosteric site. Binding causes interactions within an enzyme that lead to conformational changes, which alter the active site enough to prevent catalysis. Binding is reversible. **C1.1.15** ➢ Competitive inhibition as a consequence of an inhibitor binding reversibly to an active site ➢ Use statins as an example of competitive inhibitors. Include the difference between competitive and non- competitive inhibition in the interactions between substrate and inhibitor and therefore in the effect of substrate concentration. **C1.1.16** ➢ Regulation of metabolic pathways by feedback inhibition ➢ Use the pathway that produces isoleucine as an example of an end product acting as an inhibitor. **C1.1.17** ➢ Mechanism-based inhibition as a consequence of chemical changes to the active site caused by the irreversible binding of an inhibitor	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Use penicillin as an example. Include the change to transpeptidases that confers resistance to penicillin.	

D1.1.1 **DNA Replication** • **Semi-conservative** • **DNA Replication** • **PCR** • **Gel Electrophesis**	**D1.1.1** ➢ DNA replication as production of exact copies of DNA with identical base sequences ➢ Students should appreciate that DNA replication is required for reproduction and for growth and tissue replacement in multicellular organisms. **D1.1.2** ➢ Semi-conservative nature of DNA replication and role of complementary base pairing ➢ Students should understand how these processes allow a high degree of accuracy in copying base sequences. **D1.1.3** ➢ Role of helicase and DNA polymerase in DNA replication ➢ Limit to the role of helicase in unwinding and breaking hydrogen bonds between DNA strands and the general role of DNA polymerase. **D1.1.4** ➢ Polymerase chain reaction and gel electrophoresis as tools for amplifying and separating DNA ➢ Students should understand the use of primers, temperature changes and Taq polymerase in the polymerase chain reaction (PCR) and the basis of separation of DNA fragments in gel electrophoresis. **D1.1.5** ➢ Applications of polymerase chain reaction and gel electrophoresis ➢ Students should appreciate the broad range of applications, including DNA profiling for paternity and forensic investigations. NOS: Reliability is enhanced by increasing the number of measurements in an experiment or test. In DNA profiling, increasing the number of markers used reduces the probability of a false match	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

D1.2.1 Transcription • **RNA Synthesis** • **Transcription** • **Types of RNA** • **Gene expression**	**D1.2.1** ➢ Transcription as the synthesis of RNA using a DNA template ➢ Students should understand the roles of RNA polymerase in this process. **D1.2.2** ➢ Role of hydrogen bonding and complementary base pairing in transcription ➢ Include the pairing of adenine (A) on the DNA template strand with uracil (U) on the RNA strand. **D1.2.3** ➢ Stability of DNA templates ➢ Single DNA strands can be used as a template for transcribing a base sequence, without the DNA base sequence changing. In somatic cells that do not divide, such sequences must be conserved throughout the life of a cell. **D1.2.4** ➢ Transcription as a process required for the expression of genes ➢ Limit to understanding that not all genes in a cell are expressed at any given time and that transcription, being the first stage of gene expression, is a key stage at which expression of a gene can be switched on and off. **D1.2.6** ➢ Roles of mRNA, ribosomes and tRNA in translation ➢ Students should know that mRNA binds to the small subunit of the ribosome and that two tRNAs can bind simultaneously to the large subunits	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

D1.2.5 Translation **Protein slation** **Genetic Code** **Mutations**	**D1.2.5** ➢ Translation as the synthesis of polypeptides from mRNA ➢ The base sequence of mRNA is translated into the amino acid sequence of a polypeptide. **D1.2.6** ➢ Roles of mRNA, ribosomes and tRNA in translation ➢ Students should know that mRNA binds to the small subunit of the ribosome and that two tRNAs can bind simultaneously to the large subunit. **D1.2.7** ➢ Complementary base pairing between tRNA and mRNA ➢ Include the terms "codon" and "anticodon". **D1.2.8** ➢ Features of the genetic code ➢ Students should understand the reasons for a triplet code. Students should use and understand the terms "degeneracy" and "universality". **D1.2.9** ➢ Using the genetic code expressed as a table of mRNA codons ➢ Students should be able to deduce the sequence of amino acids coded by an mRNA strand. **D1.2.10** ➢ Stepwise movement of the ribosome along mRNA and linkage of amino acids by peptide bonding to the growing polypeptide chain ➢ Focus on elongation of the polypeptide, rather than on initiation and termination.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	D1.2.11 ➢ Mutations that change protein structure ➢ Include an example of a point mutation affecting protein structure.	
C1.2.1 Cell Respiration • **Energy** • **Co enzymes** • **Cell Respiration** • **Respiration Types** • **Limiting Factors**	**C1.2.1** ➢ ATP as the molecule that distributes energy within cells ➢ Include the full name of ATP (adenosine triphosphate) and that it is a nucleotide. Students should appreciate the properties of ATP that make it suitable for use as the energy currency within cells. **C1.2.2** ➢ Life processes within cells that ATP supplies with energy ➢ Include active transport across membranes, synthesis of macromolecules (anabolism), movement of the whole cell or cell components such as chromosomes. **C1.2.3** ➢ Energy transfers during interconversions between ATP and ADP ➢ Students should know that energy is released by hydrolysis of ATP (adenosine triphosphate) to ADP (adenosine diphosphate) and phosphate, but energy is required to synthesize ATP from ADP and phosphate. Students are not required to know the quantity of energy in kilojoules, but students should appreciate that it is sufficient for many tasks in the cell. **C1.2.4**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Cell respiration as a system for producing ATP within the cell using energy released from carbon compounds ➢ Students should appreciate that glucose and fatty acids are the principal substrates for cell respiration but that a wide range of carbon/organic compounds can be used. Students should be able to distinguish between the processes of cell respiration and gas exchange. **C1.2.5** ➢ Differences between anaerobic and aerobic cell respiration in humans ➢ Include which respiratory substrates can be used, whether oxygen is required, relative yields of ATP, types of waste product and where the reactions occur in a cell. Students should be able to write simple word equations for both types of respiration, with glucose as the substrate. Students should appreciate that mitochondria are required for aerobic, but not anaerobic, respiration. **C1.2.6** ➢ Variables affecting the rate of cell respiration ➢ AOS: Students should make measurements allowing for the determination of the rate of cell respiration. Students should also be able to calculate the rate of cellular respiration from raw data that they have generated experimentally or from secondary data.	

• **Hydrogen Carriers** • **Glycolysis** • **Fermentation** • **Link Reaction** • **Krebs Cycle**	**C1.2.7** ➢ Role of NAD as a carrier of hydrogen and oxidation by removal of hydrogen during cell respiration ➢ Students should understand that oxidation is a process of electron loss, so when hydrogen with an electron is removed from a substrate (dehydrogenation) the substrate has been oxidized. They should appreciate that redox reactions involve both oxidation and reduction, and that NAD is reduced when it accepts hydrogen. **C1.2.8** ➢ Conversion of glucose to pyruvate by stepwise reactions in glycolysis with a net yield of ATP and reduced NAD ➢ Include phosphorylation, lysis, oxidation and ATP formation. Students are not required to know the names of the intermediates, but students should know that each step in the pathway is catalysed by a different enzyme. **C1.2.9** ➢ Conversion of pyruvate to lactate as a means of regenerating NAD in anaerobic cell respiration ➢ Regeneration of NAD allows glycolysis to continue, with a net yield of two ATP molecules per molecule of glucose. **C1.2.10** ➢ Anaerobic cell respiration in yeast and its use in brewing and baking ➢ Students should understand that the pathways of anaerobic respiration are the same in humans and yeasts apart from the regeneration of NAD using pyruvate and therefore the final products. **C1.2.11** ➢ Oxidation and decarboxylation of pyruvate as a link reaction in aerobic cell respiration ➢ Students should understand that lipids and carbohydrates are metabolized to form acetyl groups (2C), which are transferred by coenzyme A to the Krebs cycle.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	C1.2.12 ➢ Oxidation and decarboxylation of acetyl groups in the Krebs cycle with a yield of ATP and reduced NAD ➢ Students are required to name only the intermediates citrate (6C) and oxaloacetate (4C). Students should appreciate that citrate is produced by transfer of an acetyl group to oxaloacetate and that oxaloacetate is regenerated by the reactions of the Krebs cycle, including four oxidations and two decarboxylations. They should also appreciate that the oxidations are dehydrogenation reactions. **C1.2.13** ➢ Transfer of energy by reduced NAD to the electron transport chain in the mitochondrion ➢ Energy is transferred when a pair of electrons is passed to the first carrier in the chain, converting reduced NAD back to NAD. Students should understand that reduced NAD comes from glycolysis, the link reaction and the Krebs cycle. **C1.2.14** ➢ Generation of a proton gradient by flow of electrons along the electron transport chain ➢ Students are not required to know the names of protein complexes. **C1.2.15** ➢ Chemiosmosis and the synthesis of ATP in the mitochondrion ➢ Students should understand how ATP synthase couples release of energy from the proton gradient with phosphorylation of ADP. **C1.2.16** ➢ Role of oxygen as terminal electron acceptor in aerobic cell respiration ➢ Oxygen accepts electrons from the electron transport chain and protons from the matrix of the mitochondrion, producing metabolic water and allowing continued flow of electrons along the chain. **C1.2.17** ➢ Differences between lipids and carbohydrates as respiratory substrates	

	➢ Include the higher yield of energy per gram of lipids, due to less oxygen and more oxidizable hydrogen and carbon. Also include glycolysis and anaerobic respiration occurring only if carbohydrate is the substrate, with 2C acetyl groups from the breakdown of fatty acids entering the pathway via acetyl-CoA (acetyl coenzyme A).	

C1.3.1 Photosynthesis • **Pigments** • **Chromatography** • **Action spectra** • **Light dependent** • **Light independent** • **Limiting Factors** • **CO_2 Experiments**	**C1.3.1** ➢ Transformation of light energy to chemical energy when carbon compounds are produced in photosynthesis ➢ This energy transformation supplies most of the chemical energy needed for life processes in ecosystems. **C1.3.2** ➢ Conversion of carbon dioxide to glucose in photosynthesis using hydrogen obtained by splitting water ➢ Students should be able to write a simple word equation for photosynthesis, with glucose as the product. **C1.3.3** ➢ Oxygen as a by-product of photosynthesis in plants, algae and cyanobacteria ➢ Students should know the simple word equation for photosynthesis. They should know that the oxygen produced by photosynthesis comes from the splitting of water. **C1.3.4** ➢ Separation and identification of photosynthetic pigments by chromatography ➢ AOS: Students should be able to calculate *Rf* values from the results of chromatographic separation of photosynthetic pigments and identify them by colour and by values. Thin-layer chromatography or paper chromatography can be used.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	C1.3.5 ➢ Absorption of specific wavelengths of light by photosynthetic pigments ➢ Include excitation of electrons within a pigment molecule, transformation of light energy to chemical energy and the reason that only some wavelengths are absorbed. Students should be familiar with absorption spectra. Include both wavelengths and colours of light in the horizontal axis of absorption spectra. **C1.3.6** ➢ Similarities and differences of absorption and action spectra ➢ AOS: Students should be able to determine rates of photosynthesis from data for oxygen production and carbon dioxide consumption for varying wavelengths. They should also be able to plot this data to make an action spectrum. **C1.3.7** ➢ Techniques for varying concentrations of carbon dioxide, light intensity or temperature experimentally to investigate the effects of limiting factors on the rate of photosynthesis ➢ AOS: Students should be able to suggest hypotheses for the effects of these limiting factors and to test these through experimentation. NOS: Hypotheses are provisional explanations that require repeated testing. During scientific research, hypotheses can either be based on theories and then tested in an experiment or be based on evidence from an experiment already carried out. Students can decide in this case whether to suggest hypotheses for the effects of limiting factors on photosynthesis before or after performing their experiments. Students should be able to identify the dependent and independent variable in an experiment. **C1.3.8** ➢ Carbon dioxide enrichment experiments as a means of predicting future rates of photosynthesis and plant growth	

	➢ Include enclosed greenhouse experiments and free-air carbon dioxide enrichment experiments (FACE). NOS: Finding methods for careful control of variables is part of experimental design. This may be easier in the laboratory but some experiments can only be done in the field. Field experiments include those performed in natural ecosystems. Students should be able to identify a controlled variable in an experiment.	

• **Photosynthesis(II)** • **Thylakoids/Grana** • **Photosystems** • **Photoreactions** • **Calvin Cycle** • **Organic synthesis**	**C1.3.9** ➢ Photosystems as arrays of pigment molecules that can generate and emit excited electrons ➢ Students should know that photosystems are always located in membranes and that they occur in cyanobacteria and in the chloroplasts of photosynthetic eukaryotes. Photosystems should be described as molecular arrays of chlorophyll and accessory pigments with a special chlorophyll as the reaction centre from which an excited electron is emitted. **C1.3.10** ➢ Advantages of the structured array of different types of pigment molecules in a photosystem ➢ Students should appreciate that a single molecule of chlorophyll or any other pigment would not be able to perform any part of photosynthesis. **C1.3.11** ➢ Generation of oxygen by the photolysis of water in photosystem II ➢ Emphasize that the protons and electrons generated by photolysis are used in photosynthesis but oxygen is a waste product. The advent of oxygen generation by photolysis had immense consequences for living organisms and geological processes on Earth. **C1.3.12** ➢ ATP production by chemiosmosis in thylakoids ➢ Include the proton gradient, ATP synthase, and proton pumping by the chain of electron carriers. Students should know that electrons are sourced, either from photosystem I in cyclic photophosphorylation or from photosystem II in non-cyclic photophosphorylation, and then used in ATP production. **C1.3.13** ➢ Reduction of NADP by photosystem I ➢ Students should appreciate that NADP is reduced by accepting two electrons that have come from photosystem I. It also accepts a hydrogen ion that has come from the stroma. The paired terms “NADP and reduced NADP” or “NADP+ and NADPH” should be paired consistently. **C1.3.14**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

- Thylakoids as systems for performing the light-dependent reactions of photosynthesis
- Students should appreciate where photolysis of water, synthesis of ATP by chemiosmosis and reduction of NADP occur in a thylakoid.

C1.3.15

- Carbon fixation by Rubisco
- Students should know the names of the substrates RuBP and CO2 and the product glycerate 3-phosphate. They should also know that Rubisco is the most abundant enzyme on Earth and that high concentrations of it are needed in the stroma of chloroplasts because it works relatively slowly and is not effective in low carbon dioxide concentrations.

C1.3.16

- Synthesis of triose phosphate using reduced NADP and ATP
- Students should know that glycerate-3-phosphate (GP) is converted into triose phosphate (TP) using NADPH and ATP.

C1.3.17

- Regeneration of RuBP in the Calvin cycle using ATP
- Students are not required to know details of the individual reactions, but students should understand that five molecules of triose phosphate are converted to three molecules of RuBP, allowing the Calvin cycle to continue. If glucose is the product of photosynthesis, five-sixths of all the triose phosphate produced must be converted back to RuBP.

C1.3.18

- Synthesis of carbohydrates, amino acids and other carbon compounds using the products of the Calvin cycle and mineral nutrients
- Students are not required to know details of metabolic pathways, but students should understand that all of the carbon in compounds in photosynthesizing organisms is fixed in the Calvin cycle and that carbon compounds other than glucose are made by metabolic pathways that can be traced back to an intermediate in the cycle.

C1.3.19

- Interdependence of the light-dependent and light-independent reactions

	➢ Students should understand how a lack of light stops light-dependent reactions and how a lack of CO2 prevents photosystem II from functioning.	
D1.3.1 Genetics ➢ Genes vs Alleles ➢ Mutations ➢ Types of Mutations ➢ Genetic Variation ➢ Genetic Diseases	**D1.3.1** ➢ Gene mutations as structural changes to genes at the molecular level ➢ Distinguish between substitutions, insertions and deletions. **D1.3.2** ➢ Consequences of base substitutions ➢ Students should understand that single-nucleotide polymorphisms (SNPs) are the result of base substitution mutations and that because of the degeneracy of the genetic code they may or may not change a single amino acid in a polypeptide. **D1.3.3** ➢ Consequences of insertions and deletions ➢ Include the likelihood of polypeptides ceasing to function, either through frameshift changes or through major insertions or deletions. Specific examples are not required.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	D1.3.4 ➢ Causes of gene mutation ➢ Students should understand that gene mutation can be caused by mutagens and by errors in DNA replication or repair. Include examples of chemical mutagens and mutagenic forms of radiation. **D1.3.5** ➢ Randomness in mutation ➢ Students should understand that mutations can occur anywhere in the base sequences of a genome, although some bases have a higher probability of mutating than others. They should also understand that no natural mechanism is known for making a deliberate change to a particular base with the purpose of changing a trait. **D1.3.6** ➢ Consequences of mutation in germ cells and somatic cells ➢ Include inheritance of mutated genes in germ cells and cancer in somatic cells. **D1.3.7** ➢ Mutation as a source of genetic variation	

	- Students should appreciate that gene mutation is the original source of all genetic variation. Although most mutations are either harmful or neutral for an individual organism, in a species they are in the long term essential for evolution by natural selection. NOS: Commercial genetic tests can yield information about potential future health and disease risk. One possible impact is that, without expert interpretation, this information could be problematic. **D1.2.11** - Mutations that change protein structure - Include an example of a point mutation affecting protein structure.	

D2.1.1 Cell Division • **Interphase** • **Mitosis vs Meiosis** • **Mitosis** • **Meiosis** • **Cytokinesis** • **Gamete Formation** • **Non-Disjunction**	**D2.1.1** ➢ Generation of new cells in living organisms by cell division ➢ In all living organisms, a parent cell—often referred to as a mother cell—divides to produce two daughter cells. **D2.1.2** ➢ Cytokinesis as splitting of cytoplasm in a parent cell between daughter cells ➢ Students should appreciate that in an animal cell a ring of contractile actin and myosin proteins pinches a cell membrane together to split the cytoplasm, whereas in a plant cell vesicles assemble sections of membrane and cell wall to achieve splitting. **D2.1.3** ➢ Equal and unequal cytokinesis ➢ Include the idea that division of cytoplasm is usually, but not in all cases, equal and that both daughter cells must receive at least one mitochondrion and any other organelle that can only be made by dividing a pre-existing structure. Include oogenesis in humans and budding in yeast as examples of unequal cytokinesis. **D2.1.4** ➢ Roles of mitosis and meiosis in eukaryotes ➢ Emphasize that nuclear division is needed before cell division to avoid production of anucleate cells. Mitosis maintains the chromosome number and genome of cells, whereas meiosis halves the chromosome number and generates genetic diversity. **D2.1.5** ➢ DNA replication as a prerequisite for both mitosis and meiosis ➢ Students should understand that, after replication, each chromosome consists of two elongated DNA molecules (chromatids) held together until anaphase.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

	D2.1.6 ➢ Condensation and movement of chromosomes as shared features of mitosis and meiosis ➢ Include the role of histones in the condensation of DNA by supercoiling and the use of microtubules and microtubule motors to move chromosomes. **D2.1.7** ➢ Phases of mitosis ➢ Students should know the names of the phases and how the process as a whole produces two genetically identical daughter cells. **D2.1.8** ➢ Identification of phases of mitosis ➢ AOS: Students should do this using diagrams as well as with cells viewed with a microscope or in a micrograph. **D2.1.9** ➢ Meiosis as a reduction division ➢ Students should understand the terms “diploid” and “haploid” and how the two divisions of meiosis produce four haploid nuclei from one diploid nucleus. They should also understand the need for meiosis in a sexual life cycle. Students should be able to outline the two rounds of segregation in meiosis. **D2.1.10** ➢ Down syndrome and non-disjunction ➢ Use Down syndrome as an example of an error in meiosis. **D2.1.11** ➢ Meiosis as a source of variation ➢ Students should understand how meiosis generates genetic diversity by random orientation of bivalents and by crossing over	

D3.21 Inheritance • **Diploid vs Haploid** • **Genetic Crosses** • **Genotype** • **Phenotype** • **Mendelian Ratios** • **Codominance** • **Sex linkage** • **Pedigree Charts** • **Polygenic traits**	**D3.2.1** ➢ Production of haploid gametes in parents and their fusion to form a diploid zygote as the means of inheritance ➢ Students should understand that this pattern of inheritance is common to all eukaryotes with a sexual life cycle. They should also understand that a diploid cell has two copies of each autosomal gene. **D3.2.2** ➢ Methods for conducting genetic crosses in flowering plants ➢ Use the terms “P generation”, “F1 generation”, “F2 generation” and “Punnett grid”. Students should understand that pollen contains male gametes and that female gametes are located in the ovary, so pollination is needed to carry out a cross. They should also understand that plants such as peas produce both male and female gametes on the same plant, allowing self-pollination and therefore self-fertilization. Mention that genetic crosses are widely used to breed new varieties of crop or ornamental plants. **D3.2.3** ➢ Genotype as the combination of alleles inherited by an organism ➢ Students should use and understand the terms “homozygous” and “heterozygous”, and appreciate the distinction between genes and alleles. **D3.2.4** ➢ Phenotype as the observable traits of an organism resulting from genotype and environmental factors ➢ Students should be able to suggest examples of traits in humans due to genotype only and due to environment only, and also traits due to interaction between genotype and environment. **D3.2.5** ➢ Effects of dominant and recessive alleles on phenotype	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Students should understand the reasons that both a homozygous-dominant genotype and a heterozygous genotype for a particular trait will produce the same phenotype. **D3.2.6** ➢ Phenotypic plasticity as the capacity to develop traits suited to the environment experienced by an organism, by varying patterns of gene expression ➢ Phenotypic plasticity is not due to changes in genotype, and the changes in traits may be reversible during the lifetime of an individual. **D3.2.7** ➢ Phenylketonuria as an example of a human disease due to a recessive allele ➢ Phenylketonuria (PKU) is a recessive genetic condition caused by mutation in an autosomal gene that codes for the enzyme needed to convert phenylalanine to tyrosine. **D3.2.8** ➢ Single-nucleotide polymorphisms and multiple alleles in gene pools ➢ Students should understand that any number of alleles of a gene can exist in the gene pool but an individual only inherits two. **D3.2.9** ➢ ABO blood groups as an example of multiple alleles ➢ Use IA, IB and i to denote the alleles. **D3.2.10** ➢ Incomplete dominance and codominance ➢ Students should understand the differences between these patterns of inheritance at the phenotypic level. In codominance, heterozygotes have a dual phenotype. Include the AB blood type (IAIB) as an example. In incomplete dominance, heterozygotes have an intermediate phenotype. Include four o'clock flower or marvel of Peru *(Mirabilis jalapa)* as an example.	

D3.2.11

- Sex determination in humans and inheritance of genes on sex chromosomes

- Students should understand that the sex chromosome in sperm determines whether a zygote develops certain male-typical or female-typical physical characteristics and that far more genes are carried by the X chromosome than the Y chromosome.

D3.2.12

- Haemophilia as an example of a sex-linked genetic disorder
- Show alleles carried on X chromosomes as superscript letters on an uppercase X.

D3.2.13

- Pedigree charts to deduce patterns of inheritance of genetic disorders
- Students should understand the genetic basis for the prohibition of marriage between close relatives in many societies.
  NOS: Scientists draw general conclusions by inductive reasoning when they base a theory on observations of some but not all cases. A pattern of inheritance may be deduced from parts of a pedigree chart and this theory may then allow genotypes of specific individuals in the pedigree to be deduced. Students should be able to distinguish between inductive and deductive reasoning.

D3.2.14

- Continuous variation due to polygenic inheritance and/or environmental factors
- Use skin colour in humans as an example.
  AOS: Students should understand the distinction between continuous variables such as skin colour and discrete variables such as ABO blood group. They should also be able to apply measures of central tendency such as mean, median and mode.

D3.2.15

- Box-and-whisker plots to represent data for a continuous variable such as student height

- AOS: Students should use a box-and-whisker plot to display six aspects of data: outliers, minimum, first quartile, median, third quartile and maximum. A data point is categorized as an outlier if it is more than 1.5 × IQR (interquartile range) above the third quartile or below the first quartile.

C3.11 **System Integration** • **Coordination** • **Communication** • **Nerve Signalling** • **Hormone Signalling** • **Receptors** • **Central Processing** • **Effectors** • **Movement**	**C3.1.1** ➢ System integration ➢ This is a necessary process in living systems. Coordination is needed for component parts of a system to collectively perform an overall function. **C3.1.2** ➢ Cells, tissues, organs and body systems as a hierarchy of subsystems that are integrated in a multicellular living organism ➢ Students should appreciate that this integration is responsible for emergent properties. For example, a cheetah becomes an effective predator by integration of its body systems. **C3.1.3** ➢ Integration of organs in animal bodies by hormonal and nervous signalling and by transport of materials and energy ➢ Distinguish between the roles of the nervous system and endocrine system in sending messages. Using examples, emphasize the role of the blood system in transporting materials between organs. **C3.1.4** ➢ The brain as a central information integration organ ➢ Limit to the role of the brain in processing information combined from several inputs and in learning and memory. Students are not required to know details such as the role of slow-acting neurotransmitters.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3**

	C3.1.5 ➢ The spinal cord as an integrating centre for unconscious processes ➢ Students should understand the difference between conscious and unconscious processes. **C3.1.6** ➢ Input to the spinal cord and cerebral hemispheres through sensory neurons ➢ Students should understand that sensory neurons convey messages from receptor cells to the central nervous system. **C3.1.7** ➢ Output from the cerebral hemispheres to muscles through motor neurons ➢ Students should understand that muscles are stimulated to contract. **C3.1.8** ➢ Nerves as bundles of nerve fibres of both sensory and motor neurons ➢ Use a transverse section of a nerve to show the protective sheath, and myelinated and unmyelinated nerve fibres. **C3.1.10** ➢ Role of the cerebellum in coordinating skeletal muscle contraction and balance ➢ Limit to a general understanding of the role of the cerebellum in the overall control of movements of the body.	

	C3.1.13 ➢ Control of the endocrine system by the hypothalamus and pituitary gland ➢ Students should have a general understanding, but are not required to know differences between mechanisms used in the anterior and posterior pituitary. **C3.1.14** ➢ Feedback control of heart rate following sensory input from baroreceptors and chemoreceptors ➢ Include the location of baroreceptors and chemoreceptors. Baroreceptors monitor blood pressure. Chemoreceptors monitor blood pH and concentrations of oxygen and carbon dioxide. Students should understand the role of the medulla in coordinating responses and sending nerve impulses to the heart to change the heart’s stroke volume and heart rate. **C3.1.15** ➢ Feedback control of ventilation rate following sensory input from chemoreceptors ➢ Students should understand the causes of pH changes in the blood. These changes are monitored by chemoreceptors in the brainstem and lead to the control of ventilation rate using signals to the diaphragm and intercostal muscles. **C3.1.16** ➢ Control of peristalsis in the digestive system by the central nervous system and enteric nervous system ➢ Limit to initiation of swallowing of food and egestion of faeces being under voluntary control by the central nervous system (CNS) but peristalsis between these points in the digestive system being under involuntary control by the enteric nervous system (ENS). The action of the ENS ensures passage of material through the gut is coordinated.	

• Phytohormones • Phototropism • Auxin • Apical growth • Ripening	**C3.1.17** ➢ Observations of tropic responses in seedlings ➢ AOS: Students should gather qualitative data, using diagrams to record their observations of seedlings illustrating tropic responses. They could also collect quantitative data by measuring the angle of curvature of seedlings. NOS: Students should be able to distinguish between qualitative and quantitative observations and understand factors that limit the precision of measurements and their accuracy. Strategies for increasing the precision, accuracy and reliability of measurements in tropism experiments could be considered. **C3.1.18** ➢ Positive phototropism as a directional growth response to lateral light in plant shoots ➢ Students are not required to know specific examples of other tropisms. **C3.1.19** ➢ Phytohormones as signalling chemicals controlling growth, development and response to stimuli in plants ➢ Students should appreciate that a variety of chemicals are used as phytohormones in plants. **C3.1.20** ➢ Auxin efflux carriers as an example of maintaining concentration gradients of phytohormones ➢ Auxin can diffuse freely into plant cells but not out of them. Auxin efflux carriers can be positioned in a cell membrane on one side of the cell. If all cells coordinate to concentrate these carriers on the same side, auxin is actively transported from cell to cell through the plant tissue and becomes concentrated in part of the plant. **C3.1.21** ➢ Promotion of cell growth by auxin ➢ Include auxin’s promotion of hydrogen ion secretion into the apoplast, acidifying the cell wall and thus loosening cross links between cellulose molecules and facilitating cell elongation. Concentration gradients of auxin cause the differences in growth rate needed for phototropism. **C3.1.22** ➢ Interactions between auxin and cytokinin as a means of regulating root and shoot growth	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Students should understand that root tips produce cytokinin, which is transported to shoots, and shoot tips produce auxin, which is transported to roots. Interactions between these phytohormones help to ensure that root and shoot growth are integrated. **C3.1.23** ➢ Positive feedback in fruit ripening and ethylene production ➢ Ethylene (IUPAC name: ethene) stimulates the changes in fruits that occur during ripening, and ripening also stimulates increased production of ethylene. Students should understand the benefit of this positive feedback mechanism in ensuring that fruit ripening is rapid and synchronized.	
D3.3.1 Systems Regulation • **Homeostasis** • **Negative Feedback** • **Blood Sugar Level** • **Thermoregulation** • **Circadian Rhythms** • **Exercise Intensity** • **Digestive Control** • **Pain Response**	**D3.3.1** ➢ Homeostasis as maintenance of the internal environment of an organism ➢ Variables are kept within preset limits, despite fluctuations in external environment. Include body temperature, blood pH, blood glucose concentration and blood osmotic concentration as homeostatic variables in humans. **D3.3.2** ➢ Negative feedback loops in homeostasis ➢ Students should understand the reason for use of negative rather than positive feedback control in homeostasis and also that negative feedback returns homeostatic variables to the set point from values above and below the set point. **D3.3.3** ➢ Regulation of blood glucose as an example of the role of hormones in homeostasis ➢ Include control of secretion of insulin and glucagon by pancreatic endocrine cells, transport in blood and the effects on target cells.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	D3.3.4 ➢ Physiological changes that form the basis of type 1 and type 2 diabetes ➢ Students should understand the physiological changes, together with risk factors and methods of prevention and treatment. **D3.3.5** ➢ Thermoregulation as an example of negative feedback control ➢ Include the roles of peripheral thermoreceptors, the hypothalamus and pituitary gland, thyroxin and also examples of muscle and adipose tissue that act as effectors of temperature change. **D3.3.6** ➢ Thermoregulation mechanisms in humans ➢ Students should appreciate that birds and mammals regulate their body temperature by physiological and behavioural means. Students are only required to understand the details of thermoregulation for humans. Include vasodilation, vasoconstriction, shivering, sweating, uncoupled respiration in brown adipose tissue and hair erection. **C3.1.9** ➢ Pain reflex arcs as an example of involuntary responses with skeletal muscle as the effector ➢ Use the example of a reflex arc with a single interneuron in the grey matter of the spinal cord and a free sensory nerve ending in a sensory neuron as a pain receptor in the hand. **C3.1.11** ➢ Modulation of sleep patterns by melatonin secretion as a part of circadian rhythms ➢ Students should understand the diurnal pattern of melatonin secretion by the pineal gland and how it helps to establish a cycle of sleeping and waking. **C3.1.12** ➢ Epinephrine (adrenaline) secretion by the adrenal glands to prepare the body for vigorous activity ➢ Consider the widespread effects of epinephrine in the body and how these effects facilitate intense muscle contraction.	

	C3.1.14 ➢ Feedback control of heart rate following sensory input from baroreceptors and chemoreceptors ➢ Include the location of baroreceptors and chemoreceptors. Baroreceptors monitor blood pressure. Chemoreceptors monitor blood pH and concentrations of oxygen and carbon dioxide. Students should understand the role of the medulla in coordinating responses and sending nerve impulses to the heart to change the heart’s stroke volume and heart rate. **C3.1.15** ➢ Feedback control of ventilation rate following sensory input from chemoreceptors ➢ Students should understand the causes of pH changes in the blood. These changes are monitored by chemoreceptors in the brainstem and lead to the control of ventilation rate using signals to the diaphragm and intercostal muscles. **C3.1.16** ➢ Control of peristalsis in the digestive system by the central nervous system and enteric nervous system ➢ Limit to initiation of swallowing of food and egestion of faeces being under voluntary control by the central nervous system (CNS) but peristalsis between these points in the digestive system being under involuntary control by the enteric nervous system (ENS). The action of the ENS ensures passage of material through the gut is coordinated.	

B3.1.1 Respiratory System • **Gas Exchange** • **Lungs** • **Alveoli** • **Ventilation** • **Lung Capacity** • **Leaf Structure** • **Evaporation** • **Stomata**	**B3.1.1** ➢ Gas exchange as a vital function in all organisms ➢ Students should appreciate that the challenges become greater as organisms increase in size because surface area-to-volume ratio decreases with increasing size, and the distance from the centre of an organism to its exterior increases. **B3.1.2** ➢ Properties of gas-exchange surfaces ➢ Include permeability, thin tissue layer, moisture and large surface area. **B3.1.3** ➢ Maintenance of concentration gradients at exchange surfaces in animals ➢ Include dense networks of blood vessels, continuous blood flow, and ventilation with air for lungs and with water for gills. **B3.1.4** ➢ Adaptations of mammalian lungs for gas exchange ➢ Limit to the alveolar lungs of a mammal. Adaptations should include the presence of surfactant, a branched network of bronchioles, extensive capillary beds and a high surface area. **B3.1.5** ➢ Ventilation of the lungs ➢ Students should understand the role of the diaphragm, intercostal muscles, abdominal muscles and ribs. **B3.1.6** ➢ Measurement of lung volumes ➢ AOS: Students should make measurements to determine tidal volume, vital capacity, and inspiratory and expiratory reserves. **B3.1.7** ➢ Adaptations for gas exchange in leaves ➢ Leaf structure adaptations should include the waxy cuticle, epidermis, air spaces, spongy mesophyll, stomatal guard cells and veins. **B3.1.8** ➢ Distribution of tissues in a leaf ➢ Students should be able to draw and label a plan diagram to show the distribution of tissues in a transverse section of a dicotyledonous leaf.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	B3.1.9 ➢ Transpiration as a consequence of gas exchange in a leaf ➢ Students should be aware of the factors affecting the rate of transpiration. **B3.1.10** ➢ Stomatal density ➢ AOS: Students should use micrographs or perform leaf casts to determine stomatal density. NOS: Reliability of quantitative data is increased by repeating measurements. In this case, repeated counts of the number of stomata visible in the field of view at high power illustrate the variability of biological material and the need for replicate trials	
• **Haemoglobin** • **Oxygen Dissociation** • **Bohr Shift**	**B3.1.11** ➢ Adaptations of foetal and adult haemoglobin for the transport of oxygen ➢ Include cooperative binding of oxygen to haem groups and allosteric binding of carbon dioxide. **B3.1.12** ➢ Bohr shift ➢ Students should understand how an increase in carbon dioxide causes increased dissociation of oxygen and the benefits of this for actively respiring tissues. **B3.1.13** ➢ Oxygen dissociation curves as a means of representing the affinity of haemoglobin for oxygen at different oxygen concentrations ➢ Explain the S-shaped form of the curve in terms of cooperative binding	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

Cardiovascular System • **Blood vessels** • **Arteries** • **Capillaries** • **Veins** • **Blood Flow** • **Thrombosis** • **Root Structure** • **Stem Structure** • **Xylem Structure** • **Transpiration**	**B3.2.1** ➢ Adaptations of capillaries for exchange of materials between blood and the internal or external environment ➢ Adaptations should include a large surface area due to branching and narrow diameters, thin walls, and fenestrations in some capillaries where exchange needs to be particularly rapid. **B3.2.2** ➢ Structure of arteries and veins ➢ AOS: Students should be able to distinguish arteries and veins in micrographs from the structure of a vessel wall and its thickness relative to the diameter of the lumen. **B3.2.3** ➢ Adaptations of arteries for the transport of blood away from the heart ➢ Students should understand how the layers of muscle and elastic tissue in the walls of arteries help them to withstand and maintain high blood pressures. **B3.2.4** ➢ Measurement of pulse rates ➢ AOS: Students should be able to determine heart rate by feeling the carotid or radial pulse with fingertips. Traditional methods could be compared with digital ones. **B3.2.5** ➢ Adaptations of veins for the return of blood to the heart ➢ Include valves to prevent backflow and the flexibility of the wall to allow it to be compressed by muscle action. **B3.2.6** ➢ Causes and consequences of occlusion of the coronary arteries ➢ AOS: Students should be able to evaluate epidemiological data relating to the incidence of coronary heart disease. NOS: Students should understand that correlation coefficients quantify correlations between variables and allow the strength of the relationship to be assessed. Low correlation coefficients or lack of any correlation could provide evidence against a hypothesis, but even strong correlations such as that between saturated fat intake and coronary heart disease do not prove a causal link.	

	B3.2.7 ➢ Transport of water from roots to leaves during transpiration ➢ Students should understand that loss of water by transpiration from cell walls in leaf cells causes water to be drawn out of xylem vessels and through cell walls by capillary action, generating tension (negative pressure potentials). It is this tension that draws water up in the xylem. Cohesion ensures a continuous column of water. **B3.2.8** ➢ Adaptations of xylem vessels for transport of water ➢ Include the lack of cell contents and incomplete or absent end walls for unimpeded flow, lignified walls to withstand tensions, and pits for entry and exit of water. **B3.2.9** ➢ Distribution of tissues in a transverse section of the stem of a dicotyledonous plant ➢ AOS: Students should be able to draw plan diagrams from micrographs to identify the relative positions of vascular bundles, xylem, phloem, cortex and epidermis. Students should annotate the diagram with the main functions of these structures. **B3.2.10** ➢ Distribution of tissues in a transverse section of the root of a dicotyledonous plant ➢ ➢ AOS: Students should be able to draw diagrams from micrographs to identify vascular bundles, xylem and phloem, cortex and epidermis.	

• **Blood Plasms** • **Lymphatic system** • **Circulation** • **Heart Cardiac Cycle** • **Active Transport**	**B3.2.11** ➢ Release and reuptake of tissue fluid in capillaries ➢ Tissue fluid is formed by pressure filtration of plasma in capillaries. This is promoted by the higher pressure of blood from arterioles. Lower pressure in venules allows tissue fluid to drain back into capillaries. **B3.2.12** ➢ Exchange of substances between tissue fluid and cells in tissues ➢ Discuss the composition of plasma and tissue fluid. **B3.2.13** ➢ Drainage of excess tissue fluid into lymph ducts ➢ Limit to the presence of valves and thin walls with gaps in lymph ducts and return of lymph to the blood circulation. **B3.2.14** ➢ Differences between the single circulation of bony fish and the double circulation of mammals ➢ Simple circuit diagrams are sufficient to show the sequence of organs through which blood passes. **B3.2.15** ➢ Adaptations of the mammalian heart for delivering pressurized blood to the arteries ➢ Include form–function adaptations of these structures: cardiac muscle, pacemaker, atria, ventricles, atrioventricular and semilunar valves, septum and coronary vessels. Students should be able to identify these features on a diagram of the heart in the frontal plane and trace the unidirectional flow of blood from named veins to arteries. **B3.2.16** ➢ Stages in the cardiac cycle ➢ AOS: Students should understand the sequence of events in the left side of the heart that follow the initiation of the heartbeat by the sinoatrial node (the “pacemaker”). Students should be able to interpret systolic and diastolic blood pressure measurements from data and graphs.	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	B3.2.17 ➢ Generation of root pressure in xylem vessels by active transport of mineral ions ➢ Root pressure is positive pressure potential, generated to cause water movement in roots and stems when transport in xylem due to transpiration is insufficient, for example when high humidity prevents transpiration or in spring, before leaves on deciduous plants have opened. **B3.2.18** ➢ Adaptations of phloem sieve tubes and companion cells for translocation of sap ➢ Include sieve plates, reduced cytoplasm and organelles, no nucleus for sieve tube elements and presence of many mitochondria for companion cells and plasmodesmata between them. Students should appreciate how these adaptations ease the flow of sap and enhance loading of carbon compounds into phloem sieve tubes at sources and unloading of them at sinks.	

C3.2.1 Immune System • **Pathogens** • **Lines of Defence** • **Surface Barriers** • **Innate Immunity** • **Memory** • **Immunodeficiency** • **Zoonoses** • **Vaccinations** • **Outbreaks** • **antibiotics**	**C3.2.1** ➢ Pathogens as the cause of infectious diseases ➢ Students should understand that a broad range of disease-causing organisms can infect humans. A disease-causing organism is known as a pathogen, although typically the term is reserved for viruses, bacteria, fungi and protists. Archaea are not known to cause any diseases in humans. NOS: Students should be aware that careful observation can lead to important progress. For example, careful observations during 19th-century epidemics of childbed fever (due to an infection after childbirth) in Vienna and cholera in London led to breakthroughs in the control of infectious disease. **C3.2.2** ➢ Skin and mucous membranes as a primary defence ➢ The skin acts as both a physical and chemical barrier to pathogens. Students are not required to draw or label diagrams of skin. **C3.2.3** ➢ Sealing of cuts in skin by blood clotting ➢ Include release of clotting factors from platelets and the subsequent cascade pathway that results in rapid conversion of fibrinogen to fibrin by thrombin and trapping of erythrocytes to form a clot. No further details are required. **C3.2.4** ➢ Differences between the innate immune system and the adaptive immune system ➢ Include the idea that the innate system responds to broad categories of pathogen and does not change during an organism's life whereas the adaptive system responds in a specific way to particular pathogens and builds up a memory of pathogens encountered, so the immune response becomes more effective. Students are not required to know any components of the innate immune system other than phagocytes. **C3.2.5** ➢ Infection control by phagocytes ➢ Include amoeboid movement from blood to sites of infection, where phagocytes recognize pathogens, engulf them by endocytosis and digest them using enzymes from lysosomes. **C3.2.6**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Lymphocytes as cells in the adaptive immune system that cooperate to produce antibodies ➢ Students should understand that lymphocytes both circulate in the blood and are contained in lymph nodes. They should appreciate that an individual has a very large number of B-lymphocytes that each make a specific type of antibody. **C3.2.7** ➢ Antigens as recognition molecules that trigger antibody production ➢ Students should appreciate that most antigens are glycoproteins or other proteins and that they are usually located on the outer surfaces of pathogens. Antigens on the surface of erythrocytes may stimulate antibody production if transfused into a person with a different blood group. **C3.2.8** ➢ Activation of B-lymphocytes by helper T-lymphocytes ➢ Students should understand that there are antigen-specific B-cells and helper T-cells. B-cells produce antibodies and become memory cells only when they have been activated. Activation requires both direct interaction with the specific antigen and contact with a helper T-cell that has also become activated by the same type of antigen. **C3.2.9** ➢ Multiplication of activated B-lymphocytes to form clones of antibody-secreting plasma cells ➢ There are relatively small numbers of B-cells that respond to a specific antigen. To produce sufficient quantities of antibody, activated B-cells first divide by mitosis to produce large numbers of plasma B-cells that are capable of producing the same type of antibody. **C3.2.10** ➢ Immunity as a consequence of retaining memory cells ➢ Students should understand that immunity is the ability to eliminate an infectious disease from the body. It is due to the long-term survival of lymphocytes that are capable of making the specific antibodies needed to fight the infection. These are memory cells. **C3.2.11** ➢ Transmission of HIV in body fluids	

	➢ Include examples of the mechanisms of HIV (human immunodeficiency virus) transmission. **C3.2.12** ➢ Infection of lymphocytes by HIV with AIDS as a consequence ➢ Students should understand that only certain types of lymphocyte are infected and killed, but that a reduction in these lymphocytes limits the ability to produce antibodies and fight opportunistic infections. **C3.2.13** ➢ Antibiotics as chemicals that block processes occurring in bacteria but not in eukaryotic cells ➢ Include reasons that antibiotics fail to control infection with viruses. **C3.2.14** ➢ Evolution of resistance to several antibiotics in strains of pathogenic bacteria ➢ Students should understand that careful use of antibiotics is necessary to slow the emergence of multiresistant bacteria. NOS: Students should recognize that the development of new techniques can lead to new avenues of research; for example, the recent technique of searching chemical libraries is yielding new antibiotics. **C3.2.15** ➢ Zoonoses as infectious diseases that can transfer from other species to humans ➢ Illustrate the prevalence of zoonoses as infectious diseases in humans and their varied modes of infection with several examples including tuberculosis, rabies and Japanese encephalitis. Include COVID-19 as an infectious disease that has recently transferred from another species, with profound consequences for humans. **C3.2.16** ➢ Vaccines and immunization ➢ Students should understand that vaccines contain antigens, or nucleic acids (DNA or RNA) with sequences that code for antigens, and that they stimulate the development of immunity to a specific pathogen without causing the disease. **C3.2.17** ➢ Herd immunity and the prevention of epidemics	

	- Students should understand how members of a population are interdependent in building herd immunity. If a sufficient percentage of a population is immune to a disease, transmission is greatly impeded. NOS: Scientists publish their research so that other scientists can evaluate it. The media often report on the research while evaluation is still happening, and consumers need to be aware of this. Vaccines are tested rigorously and the risks of side effects are minimal but not nil. The distinction between pragmatic truths and certainty is poorly understood. **C3.2.18** - Evaluation of data related to the COVID-19 pandemic - AOS: Students should have the opportunity to calculate both percentage difference and percentage change.	

C2.2.1 Nervous System • Neurons • Resting Potentials • Action Potentials • Myelination • Synaptic transfer • Graded Potentials	**C2.2.1** ➢ Neurons as cells within the nervous system that carry electrical impulses ➢ Students should understand that cytoplasm and a nucleus form the cell body of a neuron, with elongated nerve fibres of varying length projecting from it. An axon is a long single fibre. Dendrites are multiple shorter fibres. Electrical impulses are conducted along these fibres. **C2.2.2** ➢ Generation of the resting potential by pumping to establish and maintain concentration gradients of sodium and potassium ions ➢ Students should understand how energy from ATP drives the pumping of sodium and potassium ions in opposite directions across the plasma membrane of neurons. They should understand the concept of a membrane polarization and a membrane potential and also reasons that the resting potential is negative. **C2.2.3** ➢ Nerve impulses as action potentials that are propagated along nerve fibres ➢ Students should appreciate that a nerve impulse is electrical because it involves movement of positively charged ions. **C2.2.4** ➢ Variation in the speed of nerve impulses ➢ Compare the speed of transmission in giant axons of squid and smaller non-myelinated nerve fibres. Also compare the speed in myelinated and non-myelinated fibres. AOS: Students should be able to describe negative and positive correlations and apply correlation coefficients as a mathematical tool to determine the strength of these correlations. Students should also be able to apply the coefficient of determination (R2) to evaluate the degree to which variation in the independent variable explains the variation in the dependent variable. For example, conduction speed of nerve impulses is negatively correlated with animal size, but positively correlated with axon diameter. **C2.2.5** ➢ Synapses as junctions between neurons and between neurons and effector cells	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	➢ Limit to chemical synapses, not electrical, and these can simply be referred to as synapses. Students should understand that a signal can only pass in one direction across a typical synapse. **C2.2.6** ➢ Release of neurotransmitters from a presynaptic membrane ➢ Include uptake of calcium in response to depolarization of a presynaptic membrane and its action as a signalling chemical inside a neuron. **C2.2.7** ➢ Generation of an excitatory postsynaptic potential ➢ Include diffusion of neurotransmitters across the synaptic cleft and binding to transmembrane receptors. Use acetylcholine as an example. Students should appreciate that this neurotransmitter exists in many types of synapse including neuromuscular junctions.	
• **Nerve Impulses** • **Oscilloscope Trace** • **Saltatory Conduction** • **Summation** • **Pain perception** • **Drug Interactions** • **Consciousness**	**C2.2.8** ➢ Depolarization and repolarization during action potentials ➢ Include the action of voltage-gated sodium and potassium channels and the need for a threshold potential to be reached for sodium channels to open. **C2.2.9**	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

- Propagation of an action potential along a nerve fibre/axon as a result of local currents
- Students should understand how diffusion of sodium ions both inside and outside an axon can cause the threshold potential to be reached.

C2.2.10

- Oscilloscope traces showing resting potentials and action potentials
- AOS: Students should interpret the oscilloscope trace in relation to cellular events. The number of impulses per second can be measured.

C2.2.11

- Saltatory conduction in myelinated fibres to achieve faster impulses
- Students should understand that ion pumps and channels are clustered at nodes of Ranvier and that an action potential is propagated from node to node.

C2.2.12

- Effects of exogenous chemicals on synaptic transmission
- Use neonicotinoids as an example of a pesticide that blocks synaptic transmission, and cocaine as an example of a drug that blocks reuptake of the neurotransmitter.

C2.2.13

- Inhibitory neurotransmitters and generation of inhibitory postsynaptic potentials
- Students should know that the postsynaptic membrane becomes hyperpolarized.

C2.2.14

- Summation of the effects of excitatory and inhibitory neurotransmitters in a postsynaptic neuron
- Multiple presynaptic neurons interact with all-or-nothing consequences in terms of postsynaptic depolarization.

	C2.2.15 ➢ Perception of pain by neurons with free nerve endings in the skin ➢ Students should know that these nerve endings have channels for positively charged ions, which open in response to a stimulus such as high temperature, acid, or certain chemicals such as capsaicin in chilli peppers. Entry of positively charged ions causes the threshold potential to be reached and nerve impulses then pass through the neurons to the brain, where pain is perceived. **C2.2.16** ➢ Consciousness as a property that emerges from the interaction of individual neurons in the brain ➢ Emergent properties such as consciousness are another example of the consequences of interaction.	

D3.1.1 Reproductive System • Male system • Female system • Menstrual cycle • Fertilization • IVF	**D3.1.1** ➢ Differences between sexual and asexual reproduction ➢ Include these relative advantages: asexual reproduction to produce genetically identical offspring by individuals that are adapted to an existing environment, sexual reproduction to produce offspring with new gene combinations and thus variation needed for adaptation to a changed environment. **D3.1.2** ➢ Role of meiosis and fusion of gametes in the sexual life cycle ➢ Students should appreciate that meiosis breaks up parental combinations of alleles, and fusion of gametes produces new combinations. Fusion of gametes is also known as fertilization. **D3.1.3** ➢ Differences between male and female sexes in sexual reproduction ➢ Include the prime difference that the male gamete travels to the female gamete, so it is smaller, with less food reserves than the egg. From this follow differences in the numbers of gametes and the reproductive strategies of males and females. **D3.1.4** ➢ Anatomy of the human male and female reproductive systems ➢ Students should be able to draw diagrams of the male-typical and female-typical systems and annotate them with names of structures and functions. **D3.1.5** ➢ Changes during the ovarian and uterine cycles and their hormonal regulation ➢ Include the roles of oestradiol, progesterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH) and both positive and negative feedback. The ovarian and uterine cycles together constitute the menstrual cycle. **D3.1.6** ➢ Fertilization in humans ➢ Include the fusion of a sperm's cell membrane with an egg cell membrane, entry to the egg of the sperm nucleus but destruction of the tail and mitochondria. Also include dissolution of nuclear membranes of sperm and egg nuclei and	Paper 1 assessment Paper 2 assessment AO1 AO 2 **AO3** **AO4**

	participation of all the condensed chromosomes in a joint mitosis to produce two diploid nuclei. **D3.1.7** - Use of hormones in in vitro fertilization (IVF) treatment - The normal secretion of hormones is suspended, and artificial doses of hormones induce superovulation.	

- All Diploma Programme courses are designed as two-year learning experiences.
-