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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** The evolution of multicellular organisms allowed cell specialization and cell replacement. |
| **1.1 Introduction to cells** |
| **Nature of science:** |
| **1.1.NOS1** Looking for trends and discrepancies—although most organisms conform to cell theory, there are exceptions. (3.1) | pg.3 |
| **1.1. NOS2** Ethical implications of research—research involving stem cells is growing in importance and raises ethical issues. (4.5) | Pg.15 |
| **Understandings:** |
| **1.1.U1** According to the cell theory, living organisms are composed of cells. | Pg.2 | **International-mindedness:**• Stem cell research has depended on the work of teams of scientists in many countries who share results thereby speeding up the rate of progress.However, national governments are influenced by local, cultural and religious traditions that impact on the work of scientists and the use of stem cells in therapy.**Theory of knowledge:**• There is a difference between the living and the non-living environment. How are we able to know thedifference?**Utilization:**• The use of stem cells in the treatment of disease is mostly at the experimental stage, with the exception of bone marrow stem cells. Scientists, however, anticipate the use of stem cell therapies as a standard method of treating a whole range of diseases in the near future, including heart disease and diabetes.**Aims:**• **Aim 8:** There are ethical issues involved in stem cell research, whether humans or other animals are used. Use of embryonic stem cells involves the death of early-stage embryos, but if therapeutic cloning is successfully developed the suffering of patients with a wide variety of conditions could be reduced. |
| **1.1.U2** Organisms consisting of only one cell carry out all functions of life in that cell. | Pg.8 |
| **1.1.U3** Surface area to volume ratio is important in the limitation of cell size. | Pg.9 |
| **1.1.U4** Multicellular organisms have properties that emerge from the interaction of their cellular components. | Pg.10 |
| **1.1.U5** Specialized tissues can develop by cell differentiation in multicellular organisms. | Pg.11 |
| **1.1.U6** Differentiation involves the expression of some genes and not others in a cell’s genome. | Pg.11-12 |
| **1.1.U7** The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses. | Pg.12-13 |
| **Applications and skills:** |
| **1.1.A1** Application: Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae. | Pg.7-8 |
| **1.1.A2** Application: Investigation of functions of life in *Paramecium* and one named photosynthetic unicellular organism. | Pg.9-10 |
| **1.1.A3** Application: Use of stem cells to treat Stargardt’s disease and one other named condition. | Pg.13-14 |
| **1.1.A4** Application: Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a new-born baby and from an adult’s own tissues. | Pg.15-16 |
| **1.1.S1** Skill: Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. Calculation of the magnification of drawings and the actual size of structures and ultrastructures shown in drawings or micrographs. (Practical 1) | Pg.3-6 |
| **Guidance:**• Students are expected to be able to name and briefly explain these functions of life: nutrition, metabolism, growth, response, excretion, homeostasis and reproduction.• *Chlorella* or *Scenedesmus* are suitable photosynthetic unicells, but *Euglena* should be avoided as it can feed heterotrophically.• Scale bars are useful as a way of indicating actual sizes in drawings and micrographs. |  |

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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** Eukaryotes have a much more complex cell structure than prokaryotes. |
| **1.2 Ultrastructure of cells** |
| **Nature of science:****1.2.NOS1** Developments in scientific research follow improvements in apparatus—the invention of electron microscopes led to greater understanding of cell structure. (1.8) | Pg. 17 |
| **Understandings:** | **International-mindedness:**• Microscopes were invented simultaneously in different parts of the world at a time when information travelled slowly. Modern-day communications have allowed for improvements in the ability to collaborate, enriching scientific endeavour.**Theory of knowledge:**• The world that we inhabit is limited by the world that we see. Is there any distinction to be drawn between knowledge claims dependent upon observations made by sense perception and knowledge claims dependent upon observations assisted by technology?**Utilization:**Syllabus and cross-curricular links:PhysicsTopic 4.4 Wave behaviourTopic C.1 Introduction to imagingTopic C.3 Fibreoptics**Aims:**• **Aim 8:** Developments in science, such as electron microscopy, can have economic benefits as they give commercial companies opportunities to make profits, but this can affect cooperation between scientists. |
| **1.2.U1** Prokaryotes have a simple cell structure without compartmentalization. | Pg.18-19 |
| **1.2.U2** Eukaryotes have a compartmentalized cell structure. | Pg.20-21 |
| **1.2.U3** Electron microscopes have a much higher resolution than light microscopes. | Pg.17-18 |
| **Applications and skills:** |
| **1.2.A1** Application: Structure and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cells of the leaf. | Pg.24 |
| **1.2.A2** Application: Prokaryotes divide by binary fission. | Pg.19 |
| **1.2.S1** Skill: Drawing of the ultrastructure of prokaryotic cells based on electron micrographs. | Pg.19-20 |
| **1.2.S2** Skill: Drawing of the ultrastructure of eukaryotic cells based on electron micrographs. | Pg.21-23 |
| **1.2.S3** Skill: Interpretation of electron micrographs to identify organelles and deduce the function of specialized cells. | Pg.25 |
| **Guidance:**• Drawings of prokaryotic cells should show the cell wall, pili and flagella, and plasma membrane enclosing cytoplasm that contains 70S ribosomes and a nucleoid with naked DNA.• Drawings of eukaryotic cells should show a plasma membrane enclosing cytoplasm that contains 80S ribosomes and a nucleus, mitochondria and other membrane-bound organelles are present in the  cytoplasm. Some eukaryotic cells have a cell wall. |  |

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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** The structure of biological membranes makes them fluid and dynamic. |
| **1.3 Membrane structure** |
| **Nature of science:** |
| **1.3.NOS1** Using models as representations of the real world—there are alternative models of membrane structure. (1.11) | Pg.26-27 |
| **1.3.NOS2** Falsification of theories with one theory being superseded by another—evidence falsified the Davson-Danielli model. (1.9) | Pg.27-28 |
| **Understandings:** | **Theory of knowledge:**• The explanation of the structure of the plasma membrane has changed over the years as new evidence and ways of analysis have come to light. Under what circumstances is it important to learn about theories that were later discredited?**Utilization:**Syllabus and cross-curricular links:BiologyTopic 2.3 Carbohydrates and lipidsTopic 2.6 Structure of DNA and RNA |
| **1.3.U1** Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules. | Pg.26 |
| **1.3.U2** Membrane proteins are diverse in terms of structure, position in the membrane and function. | Pg.30-31 |
| **1.3.U3** Cholesterol is a component of animal cell membranes. | Pg.32 |
| **Applications and skills:** |
| **1.3.A1** Application: Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes. | Pg.33 |
| **1.3.S1** Skill: Drawing of the fluid mosaic model. | Pg.31-32 |
| **1.3.S2** Skill: Analysis of evidence from electron microscopy that led to the proposal of the Davson-Danielli model. | Pg.28-30 |
| **1.3.S3** Skill: Analysis of the falsification of the Davson-Danielli model that led to the Singer-Nicolson model. | Pg.28-30 |
| **Guidance:**• Amphipathic phospholipids have hydrophilic and hydrophobic properties.• Drawings of the fluid mosaic model of membrane structure can be two dimensional rather than three dimensional. Individual phospholipid molecules should be shown using the symbol of a circle with two parallel lines attached. A range of membrane proteins should be shown including glycoproteins. |  |

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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** Membranes control the composition of cells by active and passive transport. |
| **1.4 Membrane transport** |
| **Nature of science:****1.4.NOS1** Experimental design—accurate quantitative measurement in osmosis experiments are essential. (3.1) | Pg.43-44 |
| **Understandings:** | **Utilization:**• Kidney dialysis artificially mimics the function of the human kidney by using appropriate membranes and diffusion gradients.Syllabus and cross-curricular links:BiologyTopic 6.5 Neurons and synapses**Aims:**• **Aim 8:** Organ donation raises some interesting ethical issues, including the altruistic nature of organ donation and concerns about sale of human organs.• **Aim 6:** Dialysis tubing experiments can act as a model of membrane action. Experiments with potato, beetroot or single-celled algae  can be used to investigate real membranes. |
| **1.4.U1** Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport. | Pg.35-38 |
| **1.4.U2** The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. | Pg.34-35 |
| **1.4.U3** Vesicles move materials within cells. | Pg.34 |
| **Applications and skills:** |
| **1.4.A1** Application: Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons. | Pg.39-41 |
| **1.4.A2** Application: Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis. | Pg.44-45 |
| **1.4.S1** Skill: Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2) | Pg.41-42 |
| **Guidance:**• Osmosis experiments are a useful opportunity to stress the need for accurate mass and volume measurements in scientific experiments. |  |

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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** There is an unbroken chain of life from the first cells on Earth to all cells in organisms alive today. |
| **1.5 The origin of cells** |
| **Nature of science:****1.5.NOS1** Testing the general principles that underlie the natural world—the principle that cells only come from pre-existing cells needs to be verified. (1.9) | Pg.47 |
| **Understandings:** | **Theory of knowledge:**• Biology is the study of life, yet life is an emergent property. Under what circumstances is a systems approach productive in biology and under what circumstances is a reductionist approach more appropriate? How do scientists decide between competing approaches?**Utilization:**Syllabus and cross-curricular links:BiologyTopic 5.1 Evidence for evolution**Aims:**• **Aim 6:** Pasteur’s experiment can be repeated using modern apparatus. |
| **1.5.U1** Cells can only be formed by division of pre-existing cells. | Pg.45-46 |
| **1.5.U2** The first cells must have arisen from non-living material. | Pg.48-49 |
| **1.5.U3** The origin of eukaryotic cells can be explained by the endosymbiotic theory. | Pg.49-50 |
| **Applications and skills:** |
| **1.5.A1** Application: Evidence from Pasteur’s experiments that spontaneous generation of cells and organisms does not now occur on Earth. | Pg.47-48 |
| **Guidance:**• Evidence for the endosymbiotic theory is expected. The origin of eukaryote cilia and flagella does not need to be included.• Students should be aware that the 64 codons in the genetic code have the same meanings in nearly all organisms, but that there are some minor variations that are likely to have accrued since the common origin of life on Earth. |  |

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| **Topic 1: Cell biology (15 hours)** |
| **Essential idea:** Cell division is essential but must be controlled |
| **1.6 Cell division** |
| **Nature of science:****1.6.NOS1** Serendipity and scientific discoveries—the discovery of cyclins was accidental. (1.4) | Pg.56 |
| **Understandings:** | **International-mindedness:**• Biologists in laboratories throughout the world are researching into thecauses and treatment of cancer.**Theory of knowledge:**• A number of scientific discoveries are claimed to be incidental or serendipitous. To what extent might some of these scientific discoveries be the result of intuition rather than luck?**Utilization:**• The mitotic index is an important prognostic tool for predicting the response of cancer cells to chemotherapy.**Aims:**• **Aim 8:** The tobacco industry could be discussed. Suppression of the results of research by tobacco companies into the health effects of smoking tobacco was unethical. Smoking causes considerable social harm, but, with the exception of laws on production and supply in Bhutan, has never been made illegal. |
| **1.6.U1** Mitosis is division of the nucleus into two genetically identical daughter nuclei. | Pg.51 |
| **1.6.U2** Chromosomes condense by supercoiling during mitosis. | Pg.52 |
| **1.6.U3** Cytokinesis occurs after mitosis and is different in plant and animal cells. | Pg.55 |
| **1.6.U4** Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm | Pg.52 |
| **1.6.U5** Cyclins are involved in the control of the cell cycle. | Pg.56 |
| **1.6.U6** Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours. | Pg.57 |
| **Applications and skills:** |
| **1.6.A1** Application: The correlation between smoking and incidence of cancers. | Pg.57-58 |
| **1.6.S1** Skill: Identification of phases of mitosis in cells viewed with a microscope or in a micrograph | Pg.52-54 |
| **1.6.S2** Skill: Determination of a mitotic index from a micrograph. | Pg.55 |
| **Guidance:**• The sequence of events in the four phases of mitosis should be known.• Preparation of temporary mounts of root squashes is recommended but phases in mitosis can also be viewed using permanent slides.• To avoid confusion in terminology, teachers are encouraged to refer to the two parts of a chromosome as sister chromatids, while they are attached to each other by a centromere in the early stages of mitosis. From anaphase onwards, when sister chromatids have separated to form individual structures, they should be referred to as chromosomes. |  |