Syllabus content

	Recommended teaching hours
Core	**95 hours**
Topic 1: Cell biology	**15**
1.1 Introduction to cells	
1.2 Ultrastructure of cells	
1.3 Membrane structure	
1.4 Membrane transport	
1.5 The origin of cells	
1.6 Cell division	
Topic 2: Molecular biology	**21**
2.1 Molecules to metabolism	
2.2 Water	
2.3 Carbohydrates and lipids	
2.4 Proteins	
2.5 Enzymes	
2.6 Structure of DNA and RNA	
2.7 DNA replication, transcription and translation	
2.8 Cell respiration	
2.9 Photosynthesis	
Topic 3: Genetics	**15**
3.1 Genes	
3.2 Chromosomes	
3.3 Meiosis	
3.4 Inheritance	
3.5 Genetic modification and biotechnology	

	Recommended teaching hours
Topic 4: Ecology	**12**
4.1 Species, communities and ecosystems	
4.2 Energy flow	
4.3 Carbon cycling	
4.4 Climate change	
Topic 5: Evolution and biodiversity	**12**
5.1 Evidence for evolution	
5.2 Natural selection	
5.3 Classification of biodiversity	
5.4 Cladistics	
Topic 6: Human physiology	**20**
6.1 Digestion and absorption	
6.2 The blood system	
6.3 Defence against infectious disease	
6.4 Gas exchange	
6.5 Neurons and synapses	
6.6 Hormones, homeostasis and reproduction	
Additional higher level (AHL)	**60 hours**
Topic 7: Nucleic acids	**9**
7.1 DNA structure and replication	
7.2 Transcription and gene expression	
7.3 Translation	
Topic 8: Metabolism, cell respiration and photosynthesis	**14**
8.1 Metabolism	
8.2 Cell respiration	
8.3 Photosynthesis	
Topic 9: Plant biology	**13**
9.1 Transport in the xylem of plants	
9.2 Transport in the phloem of plants	

	Recommended teaching hours
9.3 Growth in plants	
9.4 Reproduction in plants	
Topic 10: Genetics and evolution	**8**
10.1 Meiosis	
10.2 Inheritance	
10.3 Gene pools and speciation	
Topic 11: Animal physiology	**16**
11.1 Antibody production and vaccination	
11.2 Movement	
11.3 The kidney and osmoregulation	
11.4 Sexual reproduction	

Options 15 hours (SL)/25 hours (HL)

A: Neurobiology and behaviour

Core topics

A.1 Neural development

A.2 The human brain

A.3 Perception of stimuli

Additional higher level topics

A.4 Innate and learned behaviour

A.5 Neuropharmacology

A.6 Ethology

B: Biotechnology and bioinformatics

Core topics

B.1 Microbiology: organisms in industry

B.2 Biotechnology in agriculture

B.3 Environmental protection

Additional higher level topics

B.4 Medicine

B.5 Bioinformatics

C: Ecology and conservation

Core topics

C.1 Species and communities

C.2 Communities and ecosystems

C.3 Impacts of humans on ecosystems

C.4 Conservation of biodiversity

Additional higher level topics

C.5 Population ecology

C.6 Nitrogen and phosphorus cycles

D: Human physiology

Core topics

D.1 Human nutrition

D.2 Digestion

D.3 Functions of the liver

D.4 The heart

Additional higher level topics

D.5 Hormones and metabolism

D.6 Transport of respiratory gases

Core

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:

Looking for trends and discrepancies—although most organisms conform to cell theory, there are exceptions. (3.1)

Ethical implications of research—research involving stem cells is growing in importance and raises ethical issues. (4.5)

Understandings:

- According to the cell theory, living organisms are composed of cells.
- Organisms consisting of only one cell carry out all functions of life in that cell.
- Surface area to volume ratio is important in the limitation of cell size.
- Multicellular organisms have properties that emerge from the interaction of their cellular components.
- Specialized tissues can develop by cell differentiation in multicellular organisms.
- Differentiation involves the expression of some genes and not others in a cell's genome.
- 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.

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 the difference?

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.

1.1 Introduction to cells	
Applications and skills: • Application: Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae. • Application: Investigation of functions of life in *Paramecium* and one named photosynthetic unicellular organism. • Application: Use of stem cells to treat Stargardt's disease and one other named condition. • 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. • 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) **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.	**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.

Essential idea: Eukaryotes have a much more complex cell structure than prokaryotes.

1.2 Ultrastructure of cells

Nature of science:

Developments in scientific research follow improvements in apparatus—the invention of electron microscopes led to greater understanding of cell structure. (1.8)

Understandings:

- Prokaryotes have a simple cell structure without compartmentalization.
- Eukaryotes have a compartmentalized cell structure.
- Electron microscopes have a much higher resolution than light microscopes.

Applications and skills:

- Application: Structure and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cells of the leaf.
- Application: Prokaryotes divide by binary fission.
- Skill: Drawing of the ultrastructure of prokaryotic cells based on electron micrographs.
- Skill: Drawing of the ultrastructure of eukaryotic cells based on electron micrographs.
- Skill: Interpretation of electron micrographs to identify organelles and deduce the function of specialized cells.

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.

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:
Physics
Topic 4.4 Wave behaviour
Topic C.1 Introduction to imaging
Topic 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.

Essential idea: The structure of biological membranes makes them fluid and dynamic.

1.3 Membrane structure

Nature of science:

Using models as representations of the real world—there are alternative models of membrane structure. (1.11)

Falsification of theories with one theory being superseded by another—evidence falsified the Davson-Danielli model. (1.9)

Understandings:

- Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules.
- Membrane proteins are diverse in terms of structure, position in the membrane and function.
- Cholesterol is a component of animal cell membranes.

Applications and skills:

- Application: Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes.
- Skill: Drawing of the fluid mosaic model.
- Skill: Analysis of evidence from electron microscopy that led to the proposal of the Davson-Danielli model.
- Skill: Analysis of the falsification of the Davson-Danielli model that led to the Singer-Nicolson model.

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.

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:
Biology
Topic 2.3 Carbohydrates and lipids
Topic 2.6 Structure of DNA and RNA

Essential idea: Membranes control the composition of cells by active and passive transport.

1.4 Membrane transport	
Nature of science: Experimental design—accurate quantitative measurement in osmosis experiments are essential. (3.1)	
Understandings: • Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport. • The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. Vesicles move materials within cells. **Applications and skills:** • Application: Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons. • 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. • Skill: Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2) **Guidance:** • Osmosis experiments are a useful opportunity to stress the need for accurate mass and volume measurements in scientific experiments.	**Utilization:** • Kidney dialysis artificially mimics the function of the human kidney by using appropriate membranes and diffusion gradients. Syllabus and cross-curricular links: Biology Topic 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.

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:

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)

Understandings:

- Cells can only be formed by division of pre-existing cells.
- The first cells must have arisen from non-living material.
- The origin of eukaryotic cells can be explained by the endosymbiotic theory.

Applications and skills:

- Application: Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

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.

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:
Biology
Topic 5.1 Evidence for evolution

Aims:

- **Aim 6:** Pasteur's experiment can be repeated using modern apparatus.

Essential idea: Cell division is essential but must be controlled.

1.6 Cell division

Nature of science:

Serendipity and scientific discoveries—the discovery of cyclins was accidental. (1.4)

Understandings:

- Mitosis is division of the nucleus into two genetically identical daughter nuclei.
- Chromosomes condense by supercoiling during mitosis.
- Cytokinesis occurs after mitosis and is different in plant and animal cells.
- Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.
- Cyclins are involved in the control of the cell cycle.
- Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

Applications and skills:

- Application: The correlation between smoking and incidence of cancers.
- Skill: Identification of phases of mitosis in cells viewed with a microscope or in a micrograph.
- Skill: Determination of a mitotic index from a micrograph.

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.

International-mindedness:

- Biologists in laboratories throughout the world are researching into the causes 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.

Topic 2: Molecular biology

21 hours

Essential idea: Living organisms control their composition by a complex web of chemical reactions.

2.1 Molecules to metabolism

Nature of science:

Falsification of theories—the artificial synthesis of urea helped to falsify vitalism. (1.9)

Understandings:

- Molecular biology explains living processes in terms of the chemical substances involved.
- Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist.
- Life is based on carbon compounds including carbohydrates, lipids, proteins and nucleic acids.
- Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism.
- Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions.
- Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.

Utilization:

Syllabus and cross-curricular links:
Chemistry
Topic 4 Chemical bonding and structure
Option B Biochemistry

Aims:

- **Aim 7:** ICT can be used for molecular visualization of carbohydrates, lipids and proteins in this sub-topic and in 2.3 and 2.4.
- **Aim 6:** Food tests such as the use of iodine to identify starch or Benedict's reagent to identify reducing sugars could be carried out.

2.1 Molecules to metabolism	
Applications and skills: • Application: Urea as an example of a compound that is produced by living organisms but can also be artificially synthesized. • Skill: Drawing molecular diagrams of glucose, ribose, a saturated fatty acid and a generalized amino acid. • Skill: Identification of biochemicals such as sugars, lipids or amino acids from molecular diagrams. **Guidance:** • Only the ring forms of D-ribose, alpha–D-glucose and beta-D-glucose are expected in drawings. • Sugars include monosaccharides and disaccharides. • Only one saturated fat is expected and its specific name is not necessary. • The variable radical of amino acids can be shown as R. The structure of individual R-groups does not need to be memorized. • Students should be able to recognize from molecular diagrams that triglycerides, phospholipids and steroids are lipids. Drawings of steroids are not expected. • Proteins or parts of polypeptides should be recognized from molecular diagrams showing amino acids linked by peptide bonds.	

Essential idea: Water is the medium of life.

2.2 Water

Nature of science:

Use theories to explain natural phenomena—the theory that hydrogen bonds form between water molecules explains the properties of water. (2.2)

Understandings:

- Water molecules are polar and hydrogen bonds form between them.
- Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water.
- Substances can be hydrophilic or hydrophobic.

Applications and skills:

- Application: Comparison of the thermal properties of water with those of methane.
- Application: Use of water as a coolant in sweat.
- Application: Modes of transport of glucose, amino acids, cholesterol, fats, oxygen and sodium chloride in blood in relation to their solubility in water.

Guidance:

- Students should know at least one example of a benefit to living organisms of each property of water.
- Transparency of water and maximum density at 4°C do not need to be included.
- Comparison of the thermal properties of water and methane assists in the understanding of the significance of hydrogen bonding in water.

International-mindedness:

- There are challenges for the increasing human population in sharing water resources equitably for drinking and irrigation, electricity generation and a range of industrial and domestic processes.

Theory of knowledge:

- Claims about the "memory of water" have been categorized as pseudoscientific. What are the criteria that can be used to distinguish scientific claims from pseudoscientific claims?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 4.3 Carbon cycling
Topic 4.4 Climate change
Physics
Topic 3.1 Thermal concepts

Aims:

- **Aim 6:** Probes can be used to determine the effect of different factors likely to influence cooling with water.

Essential idea: Compounds of carbon, hydrogen and oxygen are used to supply and store energy.

2.3 Carbohydrates and lipids

Nature of science:

Evaluating claims—health claims made about lipids in diets need to be assessed. (5.2)

Understandings:

- Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers.
- Fatty acids can be saturated, monounsaturated or polyunsaturated.
- Unsaturated fatty acids can be cis or trans isomers.
- Triglycerides are formed by condensation from three fatty acids and one glycerol.

Applications and skills:

- Application: Structure and function of cellulose and starch in plants and glycogen in humans.
- Application: Scientific evidence for health risks of trans fats and saturated fatty acids.
- Application: Lipids are more suitable for long-term energy storage in humans than carbohydrates.
- Application: Evaluation of evidence and the methods used to obtain the evidence for health claims made about lipids.
- Skill: Use of molecular visualization software to compare cellulose, starch and glycogen.
- Skill: Determination of body mass index by calculation or use of a nomogram.

Guidance:

- The structure of starch should include amylose and amylopectin.
- Named examples of fatty acids are not required.
- Sucrose, lactose and maltose should be included as examples of disaccharides produced by combining monosaccharides.

International-mindedness:

- Variation in the prevalence of different health problems around the world could be discussed including obesity, dietary energy deficiency, kwashiorkor, anorexia nervosa and coronary heart disease.

Theory of knowledge:

- There are conflicting views as to the harms and benefits of fats in diets. How do we decide between competing views?

Utilization:

- Potatoes have been genetically modified to reduce the level of amylose to produce a more effective adhesive.

Syllabus and cross-curricular links:
Biology
Option B: Biotechnology and bioinformatics

Aims:

- **Aim 8:** There are social implications of obesity.

Essential idea: Proteins have a very wide range of functions in living organisms.

2.4 Proteins

Nature of science:

Looking for patterns, trends and discrepancies—most but not all organisms assemble proteins from the same amino acids. (3.1)

Understandings:

- Amino acids are linked together by condensation to form polypeptides.
- There are 20 different amino acids in polypeptides synthesized on ribosomes.
- Amino acids can be linked together in any sequence giving a huge range of possible polypeptides.
- The amino acid sequence of polypeptides is coded for by genes.
- A protein may consist of a single polypeptide or more than one polypeptide linked together.
- The amino acid sequence determines the three-dimensional conformation of a protein.
- Living organisms synthesize many different proteins with a wide range of functions.
- Every individual has a unique proteome.

Applications and skills:

- Application: Rubisco, insulin, immunoglobulins, rhodopsin, collagen and spider silk as examples of the range of protein functions.
- Application: Denaturation of proteins by heat or by deviation of pH from the optimum.
- Skill: Drawing molecular diagrams to show the formation of a peptide bond.

Utilization:

- Proteomics and the production of proteins by cells cultured in fermenters offer many opportunities for the food, pharmaceutical and other industries.

Aims:

- **Aim 7:** ICT can be used for molecular visualization of the structure of proteins.
- **Aim 8:** Obtaining samples of human blood for immunological, pharmaceutical and anthropological studies is an international endeavour with many ethical issues.

2.4 Proteins	
Guidance: • The detailed structure of the six proteins selected to illustrate the functions of proteins is not needed. • Egg white or albumin solutions can be used in denaturation experiments. • Students should know that most organisms use the same 20 amino acids in the same genetic code although there are some exceptions. Specific examples could be used for illustration.	

Essential idea: Enzymes control the metabolism of the cell.

2.5 Enzymes	
Nature of science: Experimental design—accurate, quantitative measurements in enzyme experiments require replicates to ensure reliability. (3.2)	
Understandings: • Enzymes have an active site to which specific substrates bind. • Enzyme catalysis involves molecular motion and the collision of substrates with the active site. • Temperature, pH and substrate concentration affect the rate of activity of enzymes. • Enzymes can be denatured. • Immobilized enzymes are widely used in industry. **Applications and skills:** • Application: Methods of production of lactose-free milk and its advantages. • Skill: Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes. • Skill: Experimental investigation of a factor affecting enzyme activity. (Practical 3) **Guidance:** • Lactase can be immobilized in alginate beads and experiments can then be carried out in which the lactose in milk is hydrolysed. • Students should be able to sketch graphs to show the expected effects of temperature, pH and substrate concentration on the activity of enzymes. They should be able to explain the patterns or trends apparent in these graphs.	**Theory of knowledge:** • Development of some techniques benefits particular human populations more than others. For example, the development of lactose-free milk available in Europe and North America would have greater benefit in Africa/Asia where lactose intolerance is more prevalent. The development of techniques requires financial investment. Should knowledge be shared when techniques developed in one part of the world are more applicable in another? **Utilization:** • Enzymes are extensively used in industry for the production of items from fruit juice to washing powder. Syllabus and cross-curricular links: Biology Topic 8 AHL Metabolism, cell respiration and photosynthesis

Essential idea: The structure of DNA allows efficient storage of genetic information.

2.6 Structure of DNA and RNA

Nature of science:

Using models as representation of the real world—Crick and Watson used model making to discover the structure of DNA. (1.10)

Understandings:

- The nucleic acids DNA and RNA are polymers of nucleotides.
- DNA differs from RNA in the number of strands present, the base composition and the type of pentose.
- DNA is a double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complementary base pairs.

Applications and skills:

- Application: Crick and Watson's elucidation of the structure of DNA using model making.
- Skill: Drawing simple diagrams of the structure of single nucleotides of DNA and RNA, using circles, pentagons and rectangles to represent phosphates, pentoses and bases.

Guidance:

- In diagrams of DNA structure, the helical shape does not need to be shown, but the two strands should be shown antiparallel. Adenine should be shown paired with thymine and guanine with cytosine, but the relative lengths of the purine and pyrimidine bases do not need to be recalled, nor the numbers of hydrogen bonds between the base pairs.

Theory of knowledge:

- The story of the elucidation of the structure of DNA illustrates that cooperation and collaboration among scientists exists alongside competition between research groups. To what extent is research in secret 'anti-scientific'? What is the relationship between shared and personal knowledge in the natural sciences?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.2 Water
Topic 3.5 Genetic modification and biotechnology
Topic 7 Nucleic acids

Essential Idea: Genetic information in DNA can be accurately copied and can be translated to make the proteins needed by the cell.

2.7 DNA replication, transcription and translation

Nature of science:

Obtaining evidence for scientific theories—Meselson and Stahl obtained evidence for the semi-conservative replication of DNA. (1.8)

Understandings:

- The replication of DNA is semi-conservative and depends on complementary base pairing.
- Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.
- DNA polymerase links nucleotides together to form a new strand, using the pre-existing strand as a template.
- Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.
- Translation is the synthesis of polypeptides on ribosomes.
- The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.
- Codons of three bases on mRNA correspond to one amino acid in a polypeptide.
- Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA.

Applications and skills:

- Application: Use of Taq DNA polymerase to produce multiple copies of DNA rapidly by the polymerase chain reaction (PCR).
- Application: Production of human insulin in bacteria as an example of the universality of the genetic code allowing gene transfer between species.
- Skill: Use a table of the genetic code to deduce which codon(s) corresponds to which amino acid.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 3.5 Genetic modification and biotechnology
Topic 7.2 Transcription and gene expression
Topic 7.3 Translation

Aims:

- **Aim 8:** There are ethical implications in altering the genome of an organism in order to produce proteins for medical use in humans.

2.7 DNA replication, transcription and translation	
• Skill: Analysis of Meselson and Stahl's results to obtain support for the theory of semi-conservative replication of DNA. • Skill: Use a table of mRNA codons and their corresponding amino acids to deduce the sequence of amino acids coded by a short mRNA strand of known base sequence. • Skill: Deducing the DNA base sequence for the mRNA strand. **Guidance:** • The different types of DNA polymerase do not need to be distinguished.	

Essential idea: Cell respiration supplies energy for the functions of life.

2.8 Cell respiration

Nature of science:

Assessing the ethics of scientific research—the use of invertebrates in respirometer experiments has ethical implications. (4.5)

Understandings:

- Cell respiration is the controlled release of energy from organic compounds to produce ATP.
- ATP from cell respiration is immediately available as a source of energy in the cell.
- Anaerobic cell respiration gives a small yield of ATP from glucose.
- Aerobic cell respiration requires oxygen and gives a large yield of ATP from glucose.

Applications and skills:

- Application: Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.
- Application: Lactate production in humans when anaerobic respiration is used to maximize the power of muscle contractions.
- Skill: Analysis of results from experiments involving measurement of respiration rates in germinating seeds or invertebrates using a respirometer.

Guidance:

- Details of the metabolic pathways of cell respiration are not needed but the substrates and final waste products should be known.
- There are many simple respirometers which could be used. Students are expected to know that an alkali is used to absorb CO_2, so reductions in volume are due to oxygen use. Temperature should be kept constant to avoid volume changes due to temperature fluctuations.

Aims:

- **Aim 8**: The ethics of the use of animals in experiments could be discussed in relation to respirometer experiments. Large-scale use of food plants for biofuels and the resulting impact on food prices has ethical implications.

Essential idea: Photosynthesis uses the energy in sunlight to produce the chemical energy needed for life.

2.9 Photosynthesis	
Nature of science: Experimental design—controlling relevant variables in photosynthesis experiments is essential. (3.1)	
Understandings: • Photosynthesis is the production of carbon compounds in cells using light energy. • Visible light has a range of wavelengths with violet the shortest wavelength and red the longest. • Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colours. • Oxygen is produced in photosynthesis from the photolysis of water. • Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide. • Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis. **Applications and skills:** • Application: Changes to the Earth's atmosphere, oceans and rock deposition due to photosynthesis. • Skill: Drawing an absorption spectrum for chlorophyll and an action spectrum for photosynthesis. • Skill: Design of experiments to investigate the effect of limiting factors on photosynthesis. • Skill: Separation of photosynthetic pigments by chromatograph. (Practical 4)	**Utilization:** Syllabus and cross-curricular links: Biology Topic 2.5 Enzymes

2.9 Photosynthesis	
Guidance: • Students should know that visible light has wavelengths between 400 and 700 nanometres, but they are not expected to recall the wavelengths of specific colours of light. • Water free of dissolved carbon dioxide for photosynthesis experiments can be produced by boiling and cooling water. • Paper chromatography can be used to separate photosynthetic pigments but thin layer chromatography gives better results.	

Core

Topic 3: Genetics

15 hours

Essential idea: Every living organism inherits a blueprint for life from its parents.

3.1 Genes

Nature of science:

Developments in scientific research follow improvements in technology—gene sequencers are used for the sequencing of genes. (1.8)

Understandings:

- A gene is a heritable factor that consists of a length of DNA and influences a specific characteristic.
- A gene occupies a specific position on a chromosome.
- The various specific forms of a gene are alleles.
- Alleles differ from each other by one or only a few bases.
- New alleles are formed by mutation.
- The genome is the whole of the genetic information of an organism.
- The entire base sequence of human genes was sequenced in the Human Genome Project.

Applications and skills:

- Application: The causes of sickle cell anemia, including a base substitution mutation, a change to the base sequence of mRNA transcribed from it and a change to the sequence of a polypeptide in hemoglobin.
- Application: Comparison of the number of genes in humans with other species.
- Skill: Use of a database to determine differences in the base sequence of a gene in two species.

International-mindedness:

- Sequencing of the human genome shows that all humans share the vast majority of their base sequences but also that there are many single nucleotide polymorphisms that contribute to human diversity.

Theory of knowledge:

- There is a link between sickle cell anemia and prevalence of malaria. How can we know whether there is a causal link in such cases or simply a correlation?

Aims:

- **Aim 7:** The use of a database to compare DNA base sequences.
- **Aim 8:** Ethics of patenting human genes.

3.1 Genes	
Guidance: • Students should be able to recall one specific base substitution that causes glutamic acid to be substituted by valine as the sixth amino acid in the hemoglobin polypeptide. • The number of genes in a species should not be referred to as genome size as this term is used for the total amount of DNA. At least one plant and one bacterium should be included in the comparison and at least one species with more genes and one with fewer genes than a human. • The Genbank® database can be used to search for DNA base sequences. The cytochrome C gene sequence is available for many different organisms and is of particular interest because of its use in reclassifying organisms into three domains. • Deletions, insertions and frame shift mutations do not need to be included.	

Essential idea: Chromosomes carry genes in a linear sequence that is shared by members of a species.

3.2 Chromosomes

Nature of science:

Developments in research follow improvements in techniques—autoradiography was used to establish the length of DNA molecules in chromosomes. (1.8)

Understandings:

- Prokaryotes have one chromosome consisting of a circular DNA molecule.
- Some prokaryotes also have plasmids but eukaryotes do not.
- Eukaryote chromosomes are linear DNA molecules associated with histone proteins.
- In a eukaryote species there are different chromosomes that carry different genes.
- Homologous chromosomes carry the same sequence of genes but not necessarily the same alleles of those genes.
- Diploid nuclei have pairs of homologous chromosomes.
- Haploid nuclei have one chromosome of each pair.
- The number of chromosomes is a characteristic feature of members of a species.
- A karyogram shows the chromosomes of an organism in homologous pairs of decreasing length.
- Sex is determined by sex chromosomes and autosomes are chromosomes that do not determine sex.

Applications and skills:

- Application: Cairns' technique for measuring the length of DNA molecules by autoradiography.
- Application: Comparison of genome size in T2 phage, *Escherichia coli*, *Drosophila melanogaster*, *Homo sapiens* and *Paris japonica*.

International-mindedness:

- Sequencing of the rice genome involved cooperation between biologists in 10 countries.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 1.6 Cell division

Aims:

- **Aim 6:** Staining root tip squashes and microscope examination of chromosomes is recommended but not obligatory.
- **Aim 7:** Use of databases to identify gene loci and protein products of genes.

3.2 Chromosomes	
• Application: Comparison of diploid chromosome numbers of *Homo sapiens*, *Pan troglodytes*, *Canis familiaris*, *Oryza sativa*, *Parascaris equorum*. • Application: Use of karyograms to deduce sex and diagnose Down syndrome in humans. • Skill: Use of databases to identify the locus of a human gene and its polypeptide product. **Guidance:** • The terms karyotype and karyogram have different meanings. Karyotype is a property of a cell—the number and type of chromosomes present in the nucleus, not a photograph or diagram of them. • Genome size is the total length of DNA in an organism. The examples of genome and chromosome number have been selected to allow points of interest to be raised. • The two DNA molecules formed by DNA replication prior to cell division are considered to be sister chromatids until the splitting of the centromere at the start of anaphase. After this, they are individual chromosomes.	

Essential idea: Alleles segregate during meiosis allowing new combinations to be formed by the fusion of gametes.

3.3 Meiosis

Nature of science:

Making careful observations—meiosis was discovered by microscope examination of dividing germ-line cells. (1.8)

Understandings:

- One diploid nucleus divides by meiosis to produce four haploid nuclei.
- The halving of the chromosome number allows a sexual life cycle with fusion of gametes.
- DNA is replicated before meiosis so that all chromosomes consist of two sister chromatids.
- The early stages of meiosis involve pairing of homologous chromosomes and crossing over followed by condensation.
- Orientation of pairs of homologous chromosomes prior to separation is random.
- Separation of pairs of homologous chromosomes in the first division of meiosis halves the chromosome number.
- Crossing over and random orientation promotes genetic variation.
- Fusion of gametes from different parents promotes genetic variation.

Applications and skills:

- Application: Non-disjunction can cause Down syndrome and other chromosome abnormalities.
- Application: Studies showing age of parents influences chances of non-disjunction.

Theory of knowledge:

- In 1922 the number of chromosomes counted in a human cell was 48. This remained the established number for 30 years, even though a review of photographic evidence from the time clearly showed that there were 46. For what reasons do existing beliefs carry a certain inertia?

Utilization:

- An understanding of karyotypes has allowed diagnoses to be made for the purposes of genetic counselling.

Syllabus and cross-curricular links:
Biology
Topic 1.6 Cell division
Topic 10.1 Meiosis
Topic 11.4 Sexual reproduction

Aims:

- **Aim 8:** Pre-natal screening for chromosome abnormalities gives an indication of the sex of the fetus and raises ethical issues over selective abortion of female fetuses in some countries.

3.3 Meiosis	
• Application: Description of methods used to obtain cells for karyotype analysis e.g. chorionic villus sampling and amniocentesis and the associated risks. • Skill: Drawing diagrams to show the stages of meiosis resulting in the formation of four haploid cells. **Guidance:** • Preparation of microscope slides showing meiosis is challenging and permanent slides should be available in case no cells in meiosis are visible in temporary mounts. • Drawings of the stages of meiosis do not need to include chiasmata. • The process of chiasmata formation need not be explained.	

Essential idea: The inheritance of genes follows patterns.

3.4 Inheritance	
Nature of science: Making quantitative measurements with replicates to ensure reliability. Mendel's genetic crosses with pea plants generated numerical data. (3.2)	
Understandings: • Mendel discovered the principles of inheritance with experiments in which large numbers of pea plants were crossed. • Gametes are haploid so contain only one allele of each gene. • The two alleles of each gene separate into different haploid daughter nuclei during meiosis. • Fusion of gametes results in diploid zygotes with two alleles of each gene that may be the same allele or different alleles. • Dominant alleles mask the effects of recessive alleles but co-dominant alleles have joint effects. • Many genetic diseases in humans are due to recessive alleles of autosomal genes, although some genetic diseases are due to dominant or co-dominant alleles. • Some genetic diseases are sex-linked. The pattern of inheritance is different with sex-linked genes due to their location on sex chromosomes. • Many genetic diseases have been identified in humans but most are very rare. • Radiation and mutagenic chemicals increase the mutation rate and can cause genetic diseases and cancer.	**Theory of knowledge:** • Mendel's theories were not accepted by the scientific community for a long time. What factors would encourage the acceptance of new ideas by the scientific community? **Utilization:** Syllabus and cross-curricular links: Biology Topic 1.6 Cell division **Aims:** • **Aim 8:** Social implications of diagnosis of mutations, including the effects on the family and stigmatization.

3.4 Inheritance	
Applications and skills: • Application: Inheritance of ABO blood groups. • Application: Red-green colour blindness and hemophilia as examples of sex-linked inheritance. • Application: Inheritance of cystic fibrosis and Huntington's disease. • Application: Consequences of radiation after nuclear bombing of Hiroshima and accident at Chernobyl. • Skill: Construction of Punnett grids for predicting the outcomes of monohybrid genetic crosses. • Skill: Comparison of predicted and actual outcomes of genetic crosses using real data. • Skill: Analysis of pedigree charts to deduce the pattern of inheritance of genetic diseases. **Guidance:** • Alleles carried on X chromosomes should be shown as superscript letters on an upper case X, such as X^h. • The expected notation for ABO blood group alleles is: *Phenotype* O — *Genotype* ii A — I^AI^A or I^Ai B — I^BI^B or I^Bi AB — I^AI^B	

Essential idea: Biologists have developed techniques for artificial manipulation of DNA, cells and organisms.

3.5 Genetic modification and biotechnology

Nature of science:

Assessing risks associated with scientific research—scientists attempt to assess the risks associated with genetically modified crops or livestock. (4.8)

Understandings:

- Gel electrophoresis is used to separate proteins or fragments of DNA according to size.
- PCR can be used to amplify small amounts of DNA.
- DNA profiling involves comparison of DNA.
- Genetic modification is carried out by gene transfer between species.
- Clones are groups of genetically identical organisms, derived from a single original parent cell.
- Many plant species and some animal species have natural methods of cloning.
- Animals can be cloned at the embryo stage by breaking up the embryo into more than one group of cells.
- Methods have been developed for cloning adult animals using differentiated cells.

Applications and skills:

- Application: Use of DNA profiling in paternity and forensic investigations.
- Application: Gene transfer to bacteria using plasmids makes use of restriction endonucleases and DNA ligase.
- Application: Assessment of the potential risks and benefits associated with genetic modification of crops.
- Application: Production of cloned embryos produced by somatic-cell nuclear transfer.

Theory of knowledge:

- The use of DNA for securing convictions in legal cases is well established, yet even universally accepted theories are overturned in the light of new evidence in science. What criteria are necessary for assessing the reliability of evidence?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.7 DNA replication, transcription and translation

Aims:

- **Aim 6:** The design of a rooting experiment should ideally lead to the experiment actually being carried out by students.
- **Aim 8:** The ethics of genetic modification could be discussed.

3.5 Genetic modification and biotechnology	
• Skill: Design of an experiment to assess one factor affecting the rooting of stem-cuttings. • Skill: Analysis of examples of DNA profiles. • Skill: Analysis of data on risks to monarch butterflies of Bt crops. **Guidance:** • Students should be able to deduce whether or not a man could be the father of a child from the pattern of bands on a DNA profile. • Dolly can be used as an example of somatic-cell transfer. • A plant species should be chosen for rooting experiments that forms roots readily in water or a solid medium.	

Core

Topic 4: Ecology

12 hours

Essential idea: The continued survival of living organisms including humans depends on sustainable communities.

4.1 Species, communities and ecosystems

Nature of science:

Looking for patterns, trends and discrepancies—plants and algae are mostly autotrophic but some are not. (3.1)

Understandings:

- Species are groups of organisms that can potentially interbreed to produce fertile offspring.
- Members of a species may be reproductively isolated in separate populations.
- Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).
- Consumers are heterotrophs that feed on living organisms by ingestion.
- Detritivores are heterotrophs that obtain organic nutrients from detritus by internal digestion.
- Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.
- A community is formed by populations of different species living together and interacting with each other.
- A community forms an ecosystem by its interactions with the abiotic environment.
- Autotrophs obtain inorganic nutrients from the abiotic environment.
- The supply of inorganic nutrients is maintained by nutrient cycling.
- Ecosystems have the potential to be sustainable over long periods of time.

International-mindedness:

- The need for sustainability in human activities could be discussed and the methods needed to promote this.

Utilization:

Syllabus and cross-curricular links:
Geography
Part 2A: Fresh water-issues and conflicts
Environmental systems and societies
Topic 2.1 Species and populations

Aims:

- **Aim 6:** It would be best for students to obtain data for the chi-squared test themselves, to give first-hand experience of field work techniques.

4.1 Species, communities and ecosystems	
Applications and skills: • Skill: Classifying species as autotrophs, consumers, detritivores or saprotrophs from a knowledge of their mode of nutrition. • Skill: Setting up sealed mesocosms to try to establish sustainability. (Practical 5) • Skill: Testing for association between two species using the chi-squared test with data obtained by quadrat sampling. • Skill: Recognizing and interpreting statistical significance. **Guidance:** • Mesocosms can be set up in open tanks, but sealed glass vessels are preferable because entry and exit of matter can be prevented but light can enter and heat can leave. Aquatic systems are likely to be more successful than terrestrial ones. • To obtain data for the chi-squared test, an ecosystem should be chosen in which one or more factors affecting the distribution of the chosen species varies. Sampling should be based on random numbers. In each quadrat the presence or absence of the chosen species should be recorded.	

Essential idea: Ecosystems require a continuous supply of energy to fuel life processes and to replace energy lost as heat.

4.2 Energy flow

Nature of science:

Use theories to explain natural phenomena—the concept of energy flow explains the limited length of food chains. (2.2)

Understandings:

- Most ecosystems rely on a supply of energy from sunlight.
- Light energy is converted to chemical energy in carbon compounds by photosynthesis.
- Chemical energy in carbon compounds flows through food chains by means of feeding.
- Energy released from carbon compounds by respiration is used in living organisms and converted to heat.
- Living organisms cannot convert heat to other forms of energy.
- Heat is lost from ecosystems.
- Energy losses between trophic levels restrict the length of food chains and the biomass of higher trophic levels.

Applications and skills:

- Skill: Quantitative representations of energy flow using pyramids of energy.

Guidance:

- Pyramids of number and biomass are not required. Students should be clear that biomass in terrestrial ecosystems diminishes with energy along food chains due to loss of carbon dioxide, water and other waste products, such as urea.

International-mindedness:

- The energetics of food chains is a factor in the efficiency of food production for the alleviation of world hunger.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.8 Cell respiration
Topic 2.9 Photosynthesis
Physics
Topic 2.3 Work, energy and power
Topic B.2 Thermodynamics
Environmental systems and societies
Topic 2.3 Flows of energy and matter

4.2 Energy flow	
• Pyramids of energy should be drawn to scale and should be stepped, not triangular. The terms producer, first consumer and second consumer and so on should be used, rather than first trophic level, second trophic level and so on. • The distinction between energy flow in ecosystems and cycling of inorganic nutrients should be stressed. Students should understand that there is a continuous but variable supply of energy in the form of sunlight but that the supply of nutrients in an ecosystem is finite and limited.	

Essential idea: Continued availability of carbon in ecosystems depends on carbon cycling.

4.3 Carbon cycling

Nature of science:

Making accurate, quantitative measurements—it is important to obtain reliable data on the concentration of carbon dioxide and methane in the atmosphere. (3.1)

Understandings:

- Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds.
- In aquatic ecosystems carbon is present as dissolved carbon dioxide and hydrogen carbonate ions.
- Carbon dioxide diffuses from the atmosphere or water into autotrophs.
- Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.
- Methane is produced from organic matter in anaerobic conditions by methanogenic archaeans and some diffuses into the atmosphere or accumulates in the ground.
- Methane is oxidized to carbon dioxide and water in the atmosphere.
- Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils.
- Partially decomposed organic matter from past geological eras was converted either into coal or into oil and gas that accumulate in porous rocks.
- Carbon dioxide is produced by the combustion of biomass and fossilized organic matter.
- Animals such as reef-building corals and mollusca have hard parts that are composed of calcium carbonate and can become fossilized in limestone.

Utilization:

Syllabus and cross-curricular links:
Physics
Topic 8.1 Energy sources
Chemistry
Topic C.2 Fossil fuels
Topic C.5 Environmental impact—global warming

Aims:

- **Aim 8:** The ethical implications of diverting crops such as maize from a food to a fuel crop could be considered.

4.3 Carbon cycling	
Applications and skills: • Application: Estimation of carbon fluxes due to processes in the carbon cycle. • Application: Analysis of data from air monitoring stations to explain annual fluctuations. • Skill: Construct a diagram of the carbon cycle. **Guidance:** • Carbon fluxes should be measured in gigatonnes.	

Essential idea: Concentrations of gases in the atmosphere affect climates experienced at the Earth's surface.

4.4 Climate change

Nature of science:

Assessing claims—assessment of the claims that human activities are producing climate change. (5.2)

Understandings:

- Carbon dioxide and water vapour are the most significant greenhouse gases.
- Other gases including methane and nitrogen oxides have less impact.
- The impact of a gas depends on its ability to absorb long wave radiation as well as on its concentration in the atmosphere.
- The warmed Earth emits longer wavelength radiation (heat).
- Longer wave radiation is absorbed by greenhouse gases that retain the heat in the atmosphere.
- Global temperatures and climate patterns are influenced by concentrations of greenhouse gases.
- There is a correlation between rising atmospheric concentrations of carbon dioxide since the start of the industrial revolution 200 years ago and average global temperatures.
- Recent increases in atmospheric carbon dioxide are largely due to increases in the combustion of fossilized organic matter.

Applications and skills:

- Application: Threats to coral reefs from increasing concentrations of dissolved carbon dioxide.
- Application: Correlations between global temperatures and carbon dioxide concentrations on Earth.
- Application: Evaluating claims that human activities are not causing climate change.

International-mindedness:

- Release of greenhouse gases occurs locally but has a global impact, so international cooperation to reduce emissions is essential.

Theory of knowledge:

- The precautionary principle is meant to guide decision-making in conditions where a lack of certainty exists. Is certainty ever possible in the natural sciences?

Utilization:

Syllabus and cross-curricular links:
Physics
Topic 8.2 Thermal energy transfer
Geography
Part 1.3 Patterns in environmental quality and sustainability/Atmosphere and change
Environmental systems and societies
Topic 7.2 Climate change—causes and impacts

Aims:

- **Aim 7:** Databases can be used to analyse concentrations of greenhouse gases.
- **Aim 8:** There are interesting parallels between humans that are unwilling to reduce their carbon footprint and cheating in social animals. When the level of cheating rises above a certain level, social behaviour breaks down.

4.4 Climate change	
Guidance: • Carbon dioxide, methane and water vapour should be included in discussions. • The harmful consequences of ozone depletion do not need to be discussed and it should be made clear that ozone depletion is not the cause of the enhanced greenhouse effect.	

Core

Topic 5: Evolution and biodiversity

12 hours

Essential idea: There is overwhelming evidence for the evolution of life on Earth.

5.1 Evidence for evolution

Nature of science:

Looking for patterns, trends and discrepancies—there are common features in the bone structure of vertebrate limbs despite their varied use. (3.1)

Understandings:

- Evolution occurs when heritable characteristics of a species change.
- The fossil record provides evidence for evolution.
- Selective breeding of domesticated animals shows that artificial selection can cause evolution.
- Evolution of homologous structures by adaptive radiation explains similarities in structure when there are differences in function.
- Populations of a species can gradually diverge into separate species by evolution.
- Continuous variation across the geographical range of related populations matches the concept of gradual divergence.

Applications and skills:

- Application: Development of melanistic insects in polluted areas.
- Application: Comparison of the pentadactyl limb of mammals, birds, amphibians and reptiles with different methods of locomotion.

Theory of knowledge:

- Evolutionary history is an especially challenging area of science because experiments cannot be performed to establish past events or their causes. There are nonetheless scientific methods of establishing beyond reasonable doubt what happened in some cases. How do these methods compare to those used by historians to reconstruct the past?

Utilization:

Syllabus and cross-curricular links:
Physics
Topic 7.1 Discrete energy and radioactivity
Geography
Part 1.3 Patterns in environmental quality and sustainability/Biodiversity and change
Environmental systems and societies
Topic 4 Biodiversity in ecosystems

Essential idea: The diversity of life has evolved and continues to evolve by natural selection.

5.2 Natural selection

Nature of science:

Use theories to explain natural phenomena—the theory of evolution by natural selection can explain the development of antibiotic resistance in bacteria. (2.1)

Understandings:

- Natural selection can only occur if there is variation among members of the same species.
- Mutation, meiosis and sexual reproduction cause variation between individuals in a species.
- Adaptations are characteristics that make an individual suited to its environment and way of life.
- Species tend to produce more offspring than the environment can support.
- Individuals that are better adapted tend to survive and produce more offspring while the less well adapted tend to die or produce fewer offspring.
- Individuals that reproduce pass on characteristics to their offspring.
- Natural selection increases the frequency of characteristics that make individuals better adapted and decreases the frequency of other characteristics leading to changes within the species.

Applications and skills:

- Application: Changes in beaks of finches on Daphne Major.
- Application: Evolution of antibiotic resistance in bacteria.

Guidance:

- Students should be clear that characteristics acquired during the lifetime of an individual are not heritable. The term Lamarckism is not required.

Theory of knowledge:

- Natural Selection is a theory. How much evidence is required to support a theory and what sort of counter evidence is required to refute it?

Essential idea: Species are named and classified using an internationally agreed system.

5.3 Classification of biodiversity

Nature of science:

Cooperation and collaboration between groups of scientists—scientists use the binomial system to identify a species rather than the many different local names. (4.3)

Understandings:

- The binomial system of names for species is universal among biologists and has been agreed and developed at a series of congresses.
- When species are discovered they are given scientific names using the binomial system.
- Taxonomists classify species using a hierarchy of taxa.
- All organisms are classified into three domains.
- The principal taxa for classifying eukaryotes are kingdom, phylum, class, order, family, genus and species.
- In a natural classification, the genus and accompanying higher taxa consist of all the species that have evolved from one common ancestral species.
- Taxonomists sometimes reclassify groups of species when new evidence shows that a previous taxon contains species that have evolved from different ancestral species.
- Natural classifications help in identification of species and allow the prediction of characteristics shared by species within a group.

Applications and skills:

- Application: Classification of one plant and one animal species from domain to species level.
- Application: Recognition features of bryophyta, filicinophyta, coniferophyta and angiospermophyta.

International-mindedness:

- There are international codes of nomenclature and agreements as to the principles to be followed in the classification of living organisms.

Theory of knowledge:

- The adoption of a system of binomial nomenclature is largely due to Swedish botanist and physician Carolus Linnaeus (1707–1778). Linnaeus also defined four groups of humans, and the divisions were based on both physical and social traits. By 21st-century standards, his descriptions can be regarded as racist. How does the social context of scientific work affect the methods and findings of research? Is it necessary to consider the social context when evaluating ethical aspects of knowledge claims?

5.3 Classification of biodiversity	
• Application: Recognition features of porifera, cnidaria, platylhelmintha, annelida, mollusca, arthropoda and chordata. • Application: Recognition of features of birds, mammals, amphibians, reptiles and fish. • Skill: Construction of dichotomous keys for use in identifying specimens. **Guidance:** • Archaea, eubacteria and eukaryote should be used for the three domains. • Members of these domains should be referred to as archaeans, bacteria and eukaryotes. • Students should know which plant phyla have vascular tissue, but other internal details are not required. • Recognition features expected for the selected animal phyla are those that are most useful in distinguishing the groups from each other and full descriptions of the characteristics of each phylum are not needed. • Viruses are not classified as living organisms.	

Essential idea: The ancestry of groups of species can be deduced by comparing their base or amino acid sequences.

5.4 Cladistics

Nature of science:

Falsification of theories with one theory being superseded by another—plant families have been reclassified as a result of evidence from cladistics. (1.9)

Understandings:

- A clade is a group of organisms that have evolved from a common ancestor.
- Evidence for which species are part of a clade can be obtained from the base sequences of a gene or the corresponding amino acid sequence of a protein.
- Sequence differences accumulate gradually so there is a positive correlation between the number of differences between two species and the time since they diverged from a common ancestor.
- Traits can be analogous or homologous.
- Cladograms are tree diagrams that show the most probable sequence of divergence in clades.
- Evidence from cladistics has shown that classifications of some groups based on structure did not correspond with the evolutionary origins of a group or species.

Applications and skills:

- Application: Cladograms including humans and other primates.
- Application: Reclassification of the figwort family using evidence from cladistics.
- Skill: Analysis of cladograms to deduce evolutionary relationships.

Theory of knowledge:

- A major step forward in the study of bacteria was the recognition in 1977 by Carl Woese that *Archaea* have a separate line of evolutionary descent from bacteria. Famous scientists, including Luria and Mayr, objected to his division of the prokaryotes. To what extent is conservatism in science desirable?

Topic 6: Human physiology

20 hours

Essential idea: The structure of the wall of the small intestine allows it to move, digest and absorb food.

6.1 Digestion and absorption

Nature of science:

Use models as representations of the real world—dialysis tubing can be used to model absorption in the intestine. (1.10)

Understandings:

- The contraction of circular and longitudinal muscle of the small intestine mixes the food with enzymes and moves it along the gut.
- The pancreas secretes enzymes into the lumen of the small intestine.
- Enzymes digest most macromolecules in food into monomers in the small intestine.
- Villi increase the surface area of epithelium over which absorption is carried out.
- Villi absorb monomers formed by digestion as well as mineral ions and vitamins.
- Different methods of membrane transport are required to absorb different nutrients.

Applications and skills:

- Application: Processes occurring in the small intestine that result in the digestion of starch and transport of the products of digestion to the liver.
- Application: Use of dialysis tubing to model absorption of digested food in the intestine.

Utilization:

- Some hydrolytic enzymes have economic importance, for example amylase in production of sugars from starch and in the brewing of beer.

Syllabus and cross-curricular links:
Biology
Topic 2.1 Molecules to metabolism
Topic 2.5 Enzymes

6.1 Digestion and absorption	
• Skill: Production of an annotated diagram of the digestive system. • Skill: Identification of tissue layers in transverse sections of the small intestine viewed with a microscope or in a micrograph. **Guidance:** • Students should know that amylase, lipase and an endopeptidase are secreted by the pancreas. The name trypsin and the method used to activate it are not required. • Students should know that starch, glycogen, lipids and nucleic acids are digested into monomers and that cellulose remains undigested. • Tissue layers should include longitudinal and circular muscles, mucosa and epithelium.	

Essential idea: The blood system continuously transports substances to cells and simultaneously collects waste products.

6.2 The blood system

Nature of science:

Theories are regarded as uncertain—William Harvey overturned theories developed by the ancient Greek philosopher Galen on movement of blood in the body. (1.9)

Understandings:

- Arteries convey blood at high pressure from the ventricles to the tissues of the body.
- Arteries have muscle cells and elastic fibres in their walls.
- The muscle and elastic fibres assist in maintaining blood pressure between pump cycles.
- Blood flows through tissues in capillaries. Capillaries have permeable walls that allow exchange of materials between cells in the tissue and the blood in the capillary.
- Veins collect blood at low pressure from the tissues of the body and return it to the atria of the heart.
- Valves in veins and the heart ensure circulation of blood by preventing backflow.
- There is a separate circulation for the lungs.
- The heart beat is initiated by a group of specialized muscle cells in the right atrium called the sinoatrial node.
- The sinoatrial node acts as a pacemaker.
- The sinoatrial node sends out an electrical signal that stimulates contraction as it is propagated through the walls of the atria and then the walls of the ventricles.
- The heart rate can be increased or decreased by impulses brought to the heart through two nerves from the medulla of the brain.
- Epinephrine increases the heart rate to prepare for vigorous physical activity.

Theory of knowledge:

- Our current understanding is that emotions are the product of activity in the brain rather than the heart. Is knowledge based on science more valid than knowledge based on intuition?

Utilization:

- Understanding of the structure of the cardiovascular system has allowed the development of heart surgery.

Syllabus and cross-curricular links:
Biology
Topic 2.2 Water
Topic 2.3 Carbohydrates and lipids
Topic 6.4 Gas exchange
Topic 6.6 Hormones, homeostasis and reproduction

Aims:

- **Aim 6:** A heart dissection is suggested as a means of studying heart structure.
- **Aim 8:** The social implications of coronary heart disease could be discussed.

6.2 The blood system	
Applications and skills: • Application: William Harvey's discovery of the circulation of the blood with the heart acting as the pump. • Application: Pressure changes in the left atrium, left ventricle and aorta during the cardiac cycle. • Application: Causes and consequences of occlusion of the coronary arteries. • Skill: Identification of blood vessels as arteries, capillaries or veins from the structure of their walls. • Skill: Recognition of the chambers and valves of the heart and the blood vessels connected to it in dissected hearts or in diagrams of heart structure.	

Essential idea: The human body has structures and processes that resist the continuous threat of invasion by pathogens.

6.3 Defence against infectious disease

Nature of science:

Risks associated with scientific research—Florey and Chain's tests on the safety of penicillin would not be compliant with current protocol on testing. (4.8)

Understandings:

- The skin and mucous membranes form a primary defence against pathogens that cause infectious disease.
- Cuts in the skin are sealed by blood clotting.
- Clotting factors are released from platelets.
- The cascade results in the rapid conversion of fibrinogen to fibrin by thrombin.
- Ingestion of pathogens by phagocytic white blood cells gives non-specific immunity to diseases.
- Production of antibodies by lymphocytes in response to particular pathogens gives specific immunity.
- Antibiotics block processes that occur in prokaryotic cells but not in eukaryotic cells.
- Viruses lack a metabolism and cannot therefore be treated with antibiotics. Some strains of bacteria have evolved with genes that confer resistance to antibiotics and some strains of bacteria have multiple resistance.

Applications and skills:

- Application: Causes and consequences of blood clot formation in coronary arteries.
- Application: Florey and Chain's experiments to test penicillin on bacterial infections in mice.
- Application: Effects of HIV on the immune system and methods of transmission.

International-mindedness:

- The spread and containment of diseases such as bird flu require international coordination and communication.

Utilization:

- An understanding of immunity has led to the development of vaccinations.

Syllabus and cross-curricular links:
Biology
Topic 5.2 Natural selection
Chemistry
Topic D2 Aspirin and penicillin

Aims:

- **Aim 8:** The social as well as the economic benefits of the control of bacterial diseases around the world should be stressed.
- **Aim 9:** Science has limited means in the fight against pathogens, as shown by the spread of new diseases and antibiotic-resistant bacteria.

6.3 Defence against infectious disease	
Guidance: • Diagrams of skin are not required. • Subgroups of phagocyte and lymphocyte are not required but students should be aware that some lymphocytes act as memory cells and can quickly reproduce to form a clone of plasma cells if a pathogen carrying a specific antigen is re-encountered. • The effects of HIV on the immune system should be limited to a reduction in the number of active lymphocytes and a loss of the ability to produce antibodies, leading to the development of AIDS.	

Essential idea: The lungs are actively ventilated to ensure that gas exchange can occur passively.

6.4 Gas exchange

Nature of science:

Obtain evidence for theories—epidemiological studies have contributed to our understanding of the causes of lung cancer. (1.8)

Understandings:

- Ventilation maintains concentration gradients of oxygen and carbon dioxide between air in alveoli and blood flowing in adjacent capillaries.
- Type I pneumocytes are extremely thin alveolar cells that are adapted to carry out gas exchange.
- Type II pneumocytes secrete a solution containing surfactant that creates a moist surface inside the alveoli to prevent the sides of the alveolus adhering to each other by reducing surface tension.
- Air is carried to the lungs in the trachea and bronchi and then to the alveoli in bronchioles.
- Muscle contractions cause the pressure changes inside the thorax that force air in and out of the lungs to ventilate them.
- Different muscles are required for inspiration and expiration because muscles only do work when they contract.

Applications and skills:

- Application: Causes and consequences of lung cancer.
- Application: Causes and consequences of emphysema.
- Application: External and internal intercostal muscles, and diaphragm and abdominal muscles as examples of antagonistic muscle action.
- Skill: Monitoring of ventilation in humans at rest and after mild and vigorous exercise. (Practical 6)

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 1.4 Membrane transport
Topic 1.6 Cell division
Topic 6.2 The blood system
Physics
Topic 3.2 Modelling a gas

Aims:

- **Aim 8:** The social consequences of lung cancer and emphysema could be discussed.

6.4 Gas exchange	
Guidance: • Ventilation can either be monitored by simple observation and simple apparatus or by data logging with a spirometer or chest belt and pressure meter. Ventilation rate and tidal volume should be measured, but the terms vital capacity and residual volume are not expected. • Students should be able to draw a diagram to show the structure of an alveolus and an adjacent capillary.	

Essential idea: Neurons transmit the message, synapses modulate the message.

6.5 Neurons and synapses

Nature of science:

Cooperation and collaboration between groups of scientists—biologists are contributing to research into memory and learning. (4.3)

Understandings:

- Neurons transmit electrical impulses.
- The myelination of nerve fibres allows for saltatory conduction.
- Neurons pump sodium and potassium ions across their membranes to generate a resting potential.
- An action potential consists of depolarization and repolarization of the neuron.
- Nerve impulses are action potentials propagated along the axons of neurons.
- Propagation of nerve impulses is the result of local currents that cause each successive part of the axon to reach the threshold potential.
- Synapses are junctions between neurons and between neurons and receptor or effector cells.
- When presynaptic neurons are depolarized they release a neurotransmitter into the synapse.
- A nerve impulse is only initiated if the threshold potential is reached.

Applications and skills:

- Application: Secretion and reabsorption of acetylcholine by neurons at synapses.
- Application: Blocking of synaptic transmission at cholinergic synapses in insects by binding of neonicotinoid pesticides to acetylcholine receptors.
- Skill: Analysis of oscilloscope traces showing resting potentials and action potentials.

Guidance:

- The details of structure of different types of neuron are not needed.
- Only chemical synapses are required, not electrical, and they can simply be referred to as synapses.

Utilization:

- An understanding of the workings of neurotransmitters and synapses has led to the development of numerous pharmaceuticals for the treatment of mental disorders.

Syllabus and cross-curricular links:
Biology
Topic 1.4 Membrane transport
Chemistry
Topic C6 Electrochemistry, rechargeable batteries and fuel cells
Psychology
Core: Biological level of analysis

Aims:

- **Aim 8:** The social effects of the abuse of psychoactive drugs could be considered, as could the use of the neurotoxin *Botox* for cosmetic treatments.

Essential idea: Hormones are used when signals need to be widely distributed.

6.6 Hormones, homeostasis and reproduction

Nature of science:

Developments in scientific research follow improvements in apparatus—William Harvey was hampered in his observational research into reproduction by lack of equipment. The microscope was invented 17 years after his death. (1.8)

Understandings:

- Insulin and glucagon are secreted by β and α cells of the pancreas respectively to control blood glucose concentration.
- Thyroxin is secreted by the thyroid gland to regulate the metabolic rate and help control body temperature.
- Leptin is secreted by cells in adipose tissue and acts on the hypothalamus of the brain to inhibit appetite.
- Melatonin is secreted by the pineal gland to control circadian rhythms.
- A gene on the Y chromosome causes embryonic gonads to develop as testes and secrete testosterone.
- Testosterone causes pre-natal development of male genitalia and both sperm production and development of male secondary sexual characteristics during puberty.
- Estrogen and progesterone cause pre-natal development of female reproductive organs and female secondary sexual characteristics during puberty.
- The menstrual cycle is controlled by negative and positive feedback mechanisms involving ovarian and pituitary hormones.

Applications and skills:

- Application: Causes and treatment of Type I and Type II diabetes.
- Application: Testing of leptin on patients with clinical obesity and reasons for the failure to control the disease.

Utilization:

- Hormones are used in a variety of therapies such as replacement therapies.

Syllabus and cross-curricular links:
Biology
Topic 3.2 Chromosomes
Topic 3.3 Meiosis
Topic 10.1 Meiosis
Psychology
Core: Biological level of analysis

Aims:

- **Aim 8:** Scientists are aware that the drugs women take in fertility treatment pose potential risks to health. Should scientific knowledge override compassionate considerations in treating infertile couples?

6.6 Hormones, homeostasis and reproduction	
• Application: Causes of jet lag and use of melatonin to alleviate it. • Application: The use in IVF of drugs to suspend the normal secretion of hormones, followed by the use of artificial doses of hormones to induce superovulation and establish a pregnancy. • Application: William Harvey's investigation of sexual reproduction in deer. • Skill: Annotate diagrams of the male and female reproductive system to show names of structures and their functions. **Guidance:** • The roles of FSH, LH, estrogen and progesterone in the menstrual cycle are expected. • William Harvey failed to solve the mystery of sexual reproduction because effective microscopes were not available when he was working, so fusion of gametes and subsequent embryo development remained undiscovered.	

Additional higher level

Topic 7: Nucleic acids

9 hours

Essential idea: The structure of DNA is ideally suited to its function.

7.1 DNA structure and replication

Nature of science:

Making careful observations—Rosalind Franklin's X-ray diffraction provided crucial evidence that DNA is a double helix. (1.8)

Understandings:

- Nucleosomes help to supercoil the DNA.
- DNA structure suggested a mechanism for DNA replication.
- DNA polymerases can only add nucleotides to the 3′ end of a primer.
- DNA replication is continuous on the leading strand and discontinuous on the lagging strand.
- DNA replication is carried out by a complex system of enzymes.
- Some regions of DNA do not code for proteins but have other important functions.

Applications and skills:

- Application: Rosalind Franklin's and Maurice Wilkins' investigation of DNA structure by X-ray diffraction.
- Application: Use of nucleotides containing dideoxyribonucleic acid to stop DNA replication in preparation of samples for base sequencing.
- Application: Tandem repeats are used in DNA profiling.
- Skill: Analysis of results of the Hershey and Chase experiment providing evidence that DNA is the genetic material.
- Skill: Utilization of molecular visualization software to analyse the association between protein and DNA within a nucleosome.

Theory of knowledge:

- Highly repetitive sequences were once classified as "junk DNA" showing a degree of confidence that it had no role. To what extent do the labels and categories used in the pursuit of knowledge affect the knowledge we obtain?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.6 Structure of DNA and RNA

Aims:

- **Aim 6:** Students could design models to illustrate the stages of DNA replication.

7.1 DNA structure and replication	
Guidance: • Details of DNA replication differ between prokaryotes and eukaryotes. Only the prokaryotic system is expected. • The proteins and enzymes involved in DNA replication should include helicase, DNA gyrase, single strand binding proteins, DNA primase and DNA polymerases I and III. • The regions of DNA that do not code for proteins should be limited to regulators of gene expression, introns, telomeres and genes for tRNAs.	

Essential idea: Information stored as a code in DNA is copied onto mRNA.

7.2 Transcription and gene expression

Nature of science:

Looking for patterns, trends and discrepancies—there is mounting evidence that the environment can trigger heritable changes in epigenetic factors. (3.1)

Understandings:

- Transcription occurs in a 5′ to 3′ direction.
- Nucleosomes help to regulate transcription in eukaryotes.
- Eukaryotic cells modify mRNA after transcription.
- Splicing of mRNA increases the number of different proteins an organism can produce.
- Gene expression is regulated by proteins that bind to specific base sequences in DNA.
- The environment of a cell and of an organism has an impact on gene expression.

Application and skills:

- Application: The promoter as an example of non-coding DNA with a function.
- Skill: Analysis of changes in the DNA methylation patterns.

Guidance:

- RNA polymerase adds the 5′ end of the free RNA nucleotide to the 3′ end of the growing mRNA molecule.

Theory of knowledge:

- The nature versus nurture debate concerning the relative importance of an individual's innate qualities versus those acquired through experiences is still under discussion. Is it important for science to attempt to answer this question?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.7 DNA replication, transcription and translation

Essential idea: Information transferred from DNA to mRNA is translated into an amino acid sequence.

7.3 Translation	
Nature of science: Developments in scientific research follow improvements in computing—the use of computers has enabled scientists to make advances in bioinformatics applications such as locating genes within genomes and identifying conserved sequences. (3.7)	
Understandings: • Initiation of translation involves assembly of the components that carry out the process. • Synthesis of the polypeptide involves a repeated cycle of events. • Disassembly of the components follows termination of translation. • Free ribosomes synthesize proteins for use primarily within the cell. • Bound ribosomes synthesize proteins primarily for secretion or for use in lysosomes. • Translation can occur immediately after transcription in prokaryotes due to the absence of a nuclear membrane. • The sequence and number of amino acids in the polypeptide is the primary structure. • The secondary structure is the formation of alpha helices and beta pleated sheets stabilized by hydrogen bonding. • The tertiary structure is the further folding of the polypeptide stabilized by interactions between R groups. • The quaternary structure exists in proteins with more than one polypeptide chain. **Application and skills:** • Application: tRNA-activating enzymes illustrate enzyme–substrate specificity and the role of phosphorylation. • Skill: Identification of polysomes in electron micrographs of prokaryotes and eukaryotes.	**Utilization:** Syllabus and cross-curricular links: Biology Topic 2.7 DNA replication, transcription and translation Option B: Biotechnology and bioinformatics

7.3 Translation	
• Skill: The use of molecular visualization software to analyse the structure of eukaryotic ribosomes and a tRNA molecule. **Guidance:** • Names of the tRNA binding sites are expected as well as their roles. • Examples of start and stop codons are not required. • Polar and non-polar amino acids are relevant to the bonds formed between R groups. • Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein.	

Additional higher level

Topic 8: Metabolism, cell respiration and photosynthesis — 14 hours

Essential idea: Metabolic reactions are regulated in response to the cell's needs.

8.1 Metabolism

Nature of science:

Developments in scientific research follow improvements in computing—developments in bioinformatics, such as the interrogation of databases, have facilitated research into metabolic pathways. (3.8)

Understandings:

- Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.
- Enzymes lower the activation energy of the chemical reactions that they catalyse.
- Enzyme inhibitors can be competitive or non-competitive.
- Metabolic pathways can be controlled by end-product inhibition.

Applications and skills:

- Application: End-product inhibition of the pathway that converts threonine to isoleucine.
- Application: Use of databases to identify potential new anti-malarial drugs.
- Skill: Calculating and plotting rates of reaction from raw experimental results.
- Skill: Distinguishing different types of inhibition from graphs at specified substrate concentration.

Guidance:

- Enzyme inhibition should be studied using one specific example for competitive and non-competitive inhibition.

Theory of knowledge:

- Many metabolic pathways have been described following a series of carefully controlled and repeated experiments. To what degree can looking at component parts give us knowledge of the whole?

Utilization:

- Many enzyme inhibitors have been used in medicine. For example ethanol has been used to act as a competitive inhibitor for antifreeze poisoning.
- Fomepizole, which is an inhibitor of alcohol dehydrogenase, has also been used for antifreeze poisoning.

Syllabus and cross-curricular links:
Biology
Topic 2.7 DNA replication, transcription and translation
Chemistry
Topic 6.1 Collision theory and rates of reaction

Aims:

- **Aim 6:** Experiments on enzyme inhibition can be performed.
- **Aim 7:** Computer simulations on enzyme action including metabolic inhibition are available.

Essential idea: Energy is converted to a usable form in cell respiration.

8.2 Cell respiration	
Nature of science: Paradigm shift—the chemiosmotic theory led to a paradigm shift in the field of bioenergetics. (2.3)	
Understandings: • Cell respiration involves the oxidation and reduction of electron carriers. • Phosphorylation of molecules makes them less stable. • In glycolysis, glucose is converted to pyruvate in the cytoplasm. • Glycolysis gives a small net gain of ATP without the use of oxygen. • In aerobic cell respiration pyruvate is decarboxylated and oxidized, and converted into acetyl compound and attached to coenzyme A to form acetyl coenzyme A in the link reaction. • In the Krebs cycle, the oxidation of acetyl groups is coupled to the reduction of hydrogen carriers, liberating carbon dioxide. • Energy released by oxidation reactions is carried to the cristae of the mitochondria by reduced NAD and FAD. • Transfer of electrons between carriers in the electron transport chain in the membrane of the cristae is coupled to proton pumping. • In chemiosmosis protons diffuse through ATP synthase to generate ATP. • Oxygen is needed to bind with the free protons to maintain the hydrogen gradient, resulting in the formation of water. • The structure of the mitochondrion is adapted to the function it performs.	**Theory of knowledge:** • Peter Mitchell's chemiosmotic theory encountered years of opposition before it was finally accepted. For what reasons does falsification not always result in an immediate acceptance of new theories or a paradigm shift? **Utilization:** Syllabus and cross-curricular links: Biology Topic 2.8 Cell respiration Chemistry Topic 9.1 Oxidation and reduction

8.2 Cell respiration	
Applications and skills: • Application: Electron tomography used to produce images of active mitochondria. • Skill: Analysis of diagrams of the pathways of aerobic respiration to deduce where decarboxylation and oxidation reactions occur. • Skill: Annotation of a diagram of a mitochondrion to indicate the adaptations to its function. **Guidance:** • The names of the intermediate compounds in gylcolysis and the Krebs cycle are not required.	

Essential idea: Light energy is converted into chemical energy.

8.3 Photosynthesis

Nature of science:

Developments in scientific research follow improvements in apparatus—sources of ^{14}C and autoradiography enabled Calvin to elucidate the pathways of carbon fixation. (1.8)

Understandings:

- Light-dependent reactions take place in the intermembrane space of the thylakoids.
- Light-independent reactions take place in the stroma.
- Reduced NADP and ATP are produced in the light-dependent reactions.
- Absorption of light by photosystems generates excited electrons.
- Photolysis of water generates electrons for use in the light-dependent reactions.
- Transfer of excited electrons occurs between carriers in thylakoid membranes.
- Excited electrons from Photosystem II are used to contribute to generate a proton gradient.
- ATP synthase in thylakoids generates ATP using the proton gradient.
- Excited electrons from Photosystem I are used to reduce NADP.
- In the light-independent reactions a carboxylase catalyses the carboxylation of ribulose bisphosphate.
- Glycerate 3-phosphate is reduced to triose phosphate using reduced NADP and ATP.
- Triose phosphate is used to regenerate RuBP and produce carbohydrates.
- Ribulose bisphosphate is reformed using ATP.
- The structure of the chloroplast is adapted to its function in photosynthesis.

Applications and skills:

- Application: Calvin's experiment to elucidate the carboxylation of RuBP.
- Skill: Annotation of a diagram to indicate the adaptations of a chloroplast to its function.

Theory of knowledge:

- The lollipop experiment used to work out the biochemical details of the Calvin cycle shows considerable creativity. To what extent is the creation of an elegant protocol similar to the creation of a work of art?

Utilization:

- The Global Artificial Photosynthesis (GAP) project aims to create an artificial "leaf" within the next decade. An electronic version of the leaf that creates oxygen and hydrogen from water and sunlight has already been invented and will be developed for use in the next decade.

Syllabus and cross-curricular links:
Biology
Topic 2.9 Photosynthesis
Topic 4.2 Energy flow
Topic 4.3 Carbon cycling
Chemistry
Topic 9.1 Oxidation and reduction

Aims:

- **Aim 6:** Hill´s method demonstrating electron transfer in chloroplasts by observing DCPIP reduction, immobilization of a culture of an alga such as *Scenedesmus* in alginate beads and measurement of the rate of photosynthesis by monitoring their effect on hydrogencarbonate indicator are all possible experiments.

Topic 9: Plant biology

13 hours

Essential idea: Structure and function are correlated in the xylem of plants.

9.1 Transport in the xylem of plants

Nature of science:

Use models as representations of the real world—mechanisms involved in water transport in the xylem can be investigated using apparatus and materials that show similarities in structure to plant tissues. (1.10)

Understandings:

- Transpiration is the inevitable consequence of gas exchange in the leaf.
- Plants transport water from the roots to the leaves to replace losses from transpiration.
- The cohesive property of water and the structure of the xylem vessels allow transport under tension.
- The adhesive property of water and evaporation generate tension forces in leaf cell walls.
- Active uptake of mineral ions in the roots causes absorption of water by osmosis.

Applications and skills:

- Application: Adaptations of plants in deserts and in saline soils for water conservation.
- Application: Models of water transport in xylem using simple apparatus including blotting or filter paper, porous pots and capillary tubing.
- Skill: Drawing the structure of primary xylem vessels in sections of stems based on microscope images.
- Skill: Measurement of transpiration rates using potometers. (Practical 7)
- Skill: Design of an experiment to test hypotheses about the effect of temperature or humidity on transpiration rates.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 2.2 Water
Topics 2.9 and 8.3 Photosynthesis

Aims:

- **Aim 7:** The introduction of image processing software and digital microscopes increases further the ability to gather more data to ensure reliability.
- **Aim 6:** Measurement of stomatal apertures and the distribution of stomata using leaf casts, including replicate measurements to enhance reliability, are possible experiments.

Essential idea: Structure and function are correlated in the phloem of plants.

9.2 Transport in the phloem of plants

Nature of science:

Developments in scientific research follow improvements in apparatus—experimental methods for measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide were only possible when radioisotopes became available. (1.8)

Understandings:

- Plants transport organic compounds from sources to sinks.
- Incompressibility of water allows transport along hydrostatic pressure gradients.
- Active transport is used to load organic compounds into phloem sieve tubes at the source.
- High concentrations of solutes in the phloem at the source lead to water uptake by osmosis.
- Raised hydrostatic pressure causes the contents of the phloem to flow towards sinks.

Applications and skills:

- Application: Structure–function relationships of phloem sieve tubes.
- Skill: Identification of xylem and phloem in microscope images of stem and root.
- Skill: Analysis of data from experiments measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 1.4 Membrane transport

Essential idea: Plants adapt their growth to environmental conditions.

9.3 Growth in plants

Nature of science:

Developments in scientific research follow improvements in analysis and deduction—improvements in analytical techniques allowing the detection of trace amounts of substances has led to advances in the understanding of plant hormones and their effect on gene expression. (1.8)

Understandings:

- Undifferentiated cells in the meristems of plants allow indeterminate growth.
- Mitosis and cell division in the shoot apex provide cells needed for extension of the stem and development of leaves.
- Plant hormones control growth in the shoot apex.
- Plant shoots respond to the environment by tropisms.
- Auxin efflux pumps can set up concentration gradients of auxin in plant tissue.
- Auxin influences cell growth rates by changing the pattern of gene expression.

Applications and skills:

- Application: Micropropagation of plants using tissue from the shoot apex, nutrient agar gels and growth hormones.
- Application: Use of micropropagation for rapid bulking up of new varieties, production of virus-free strains of existing varieties and propagation of orchids and other rare species.

Guidance:

- Auxin is the only named hormone that is expected.

Theory of knowledge:

- Plants communicate chemically both internally and externally. To what extent can plants be said to have language?

Utilization:

- Micropropagation is used for rapid bulking up of new varieties of plant.

Syllabus and cross-curricular links:
Biology
Topic 3.5 Genetic modification and biotechnology

Aims:

- **Aim 6:** Investigations into tropisms could be carried out.

Essential idea: Reproduction in flowering plants is influenced by the biotic and abiotic environment.

9.4 Reproduction in plants

Nature of science:

Paradigm shift—more than 85% of the world's 250,000 species of flowering plant depend on pollinators for reproduction. This knowledge has led to protecting entire ecosystems rather than individual species. (2.3)

Understandings:

- Flowering involves a change in gene expression in the shoot apex.
- The switch to flowering is a response to the length of light and dark periods in many plants.
- Success in plant reproduction depends on pollination, fertilization and seed dispersal.
- Most flowering plants use mutualistic relationships with pollinators in sexual reproduction.

Applications and skills:

- Application: Methods used to induce short-day plants to flower out of season.
- Skill: Drawing internal structure of seeds.
- Skill: Drawing of half-views of animal-pollinated flowers.
- Skill: Design of experiments to test hypotheses about factors affecting germination.

Guidance:

- Students should understand the differences between pollination, fertilization and seed dispersal but are not required to know the details of each process.
- Flowering in so-called short-day plants such as chrysanthemums, is stimulated by long nights rather than short days.

Utilization:

- The University of Göttingen, in Germany, conducted an extensive review of scientific studies from 200 countries for 115 of the leading global crops in 2005. They found that 87 of the crop plants depend to some degree upon animal pollination, including bees. This accounts for one-third of crop production globally.

Additional higher level

Topic 10: Genetics and evolution

8 hours

Essential idea: Meiosis leads to independent assortment of chromosomes and unique composition of alleles in daughter cells.

10.1 Meiosis

Nature of science:

Making careful observations—careful observation and record keeping turned up anomalous data that Mendel's law of independent assortment could not account for. Thomas Hunt Morgan developed the notion of linked genes to account for the anomalies. (1.8)

Understandings:

- Chromosomes replicate in interphase before meiosis.
- Crossing over is the exchange of DNA material between non-sister homologous chromatids.
- Crossing over produces new combinations of alleles on the chromosomes of the haploid cells.
- Chiasmata formation between non-sister chromatids can result in an exchange of alleles.
- Homologous chromosomes separate in meiosis I.
- Sister chromatids separate in meiosis II.
- Independent assortment of genes is due to the random orientation of pairs of homologous chromosomes in meiosis I.

Applications and skills:

- Skill: Drawing diagrams to show chiasmata formed by crossing over.

Guidance:

- Diagrams of chiasmata should show sister chromatids still closely aligned, except at the point where crossing over occurred and a chiasma was formed.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 1.6 Cell division
Topic 3.3 Meiosis
Topic 11.4 Sexual reproduction

Aims:

- **Aim 6:** Staining of lily anthers or other tissue containing germ-line cells and microscope examination to observe cells in meiosis are possible activities.

Essential idea: Genes may be linked or unlinked and are inherited accordingly.

10.2 Inheritance

Nature of science:

Looking for patterns, trends and discrepancies—Mendel used observations of the natural world to find and explain patterns and trends. Since then, scientists have looked for discrepancies and asked questions based on further observations to show exceptions to the rules. For example, Morgan discovered non-Mendelian ratios in his experiments with *Drosophila*. (3.1)

Understandings:

- Gene loci are said to be linked if on the same chromosome.
- Unlinked genes segregate independently as a result of meiosis.
- Variation can be discrete or continuous.
- The phenotypes of polygenic characteristics tend to show continuous variation.
- Chi-squared tests are used to determine whether the difference between an observed and expected frequency distribution is statistically significant.

Applications and skills:

- Application: Morgan's discovery of non-Mendelian ratios in *Drosophila*.
- Application: Completion and analysis of Punnett squares for dihybrid traits.
- Application: Polygenic traits such as human height may also be influenced by environmental factors.
- Skill: Calculation of the predicted genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes.
- Skill: Identification of recombinants in crosses involving two linked genes.
- Skill: Use of a chi-squared test on data from dihybrid crosses.

Theory of knowledge:

- The law of independent assortment was soon found to have exceptions when looking at linked genes. What is the difference between a law and a theory in science?

Utilization:

- An understanding of inheritance allowed farmers to selectively breed their livestock for specific characteristics.

Syllabus and cross-curricular links:
Biology
Topic 3.4 Inheritance

Aims:

- **Aim 4:** Use analytical skills to solve genetic crosses.
- **Aim 8:** Ethical issues arise in the prevention of the inheritance of genetic disorders.

10.2 Inheritance	
Guidance: • Alleles are usually shown side by side in dihybrid crosses, for example, TtBb. In representing crosses involving linkage, it is more common to show them as vertical pairs, for example: $\frac{T\ B}{t\ b}$ • This format will be used in examination papers, or students will be given sufficient information to allow them to deduce which alleles are linked.	

Essential idea: Gene pools change over time.

10.3 Gene pools and speciation

Nature of science:

Looking for patterns, trends and discrepancies—patterns of chromosome number in some genera can be explained by speciation due to polyploidy. (3.1)

Understandings:

- A gene pool consists of all the genes and their different alleles, present in an interbreeding population.
- Evolution requires that allele frequencies change with time in populations.
- Reproductive isolation of populations can be temporal, behavioural or geographic.
- Speciation due to divergence of isolated populations can be gradual.
- Speciation can occur abruptly.

Applications and skills:

- Application: Identifying examples of directional, stabilizing and disruptive selection.
- Application: Speciation in the genus *Allium* by polyploidy.
- Skill: Comparison of allele frequencies of geographically isolated populations.

Guidance:

- Punctuated equilibrium implies long periods without appreciable change and short periods of rapid evolution.

Theory of knowledge:

- Punctuated equilibrium was long considered an alternative theory of evolution and a challenge to the long established paradigm of Darwinian gradualism. How do paradigm shifts proceed in science and what factors are involved in their success?

Utilization:

- Many crop species have been created to be polyploid. Polyploidy increases allelic diversity and permits novel phenotypes to be generated. It also leads to hybrid vigour.

Syllabus and cross-curricular links:
Biology
Topic 5.1 Evidence for evolution

Topic 11: Animal physiology

16 hours

Essential idea: Immunity is based on recognition of self and destruction of foreign material.

11.1 Antibody production and vaccination

Nature of science:

Consider ethical implications of research—Jenner tested his vaccine for smallpox on a child. (4.5)

Understandings:

- Every organism has unique molecules on the surface of its cells.
- Pathogens can be species-specific although others can cross species barriers.
- B lymphocytes are activated by T lymphocytes in mammals.
- Activated B cells multiply to form clones of plasma cells and memory cells.
- Plasma cells secrete antibodies.
- Antibodies aid the destruction of pathogens.
- White cells release histamine in response to allergens.
- Histamines cause allergic symptoms.
- Immunity depends upon the persistence of memory cells.
- Vaccines contain antigens that trigger immunity but do not cause the disease.
- Fusion of a tumour cell with an antibody-producing plasma cell creates a hybridoma cell.
- Monoclonal antibodies are produced by hybridoma cells.

International-mindedness:

- The World Health Organization initiated the campaign for the global eradication of smallpox in 1967. The campaign was deemed a success in 1977, only 10 years later.

Utilization:

- Human vaccines are often produced using the immune responses of other animals.

Syllabus and cross-curricular links:
Biology
Topic 6.3 Defence against infectious disease
Topic 11.4 Sexual reproduction
Geography
Part 2F: The geography of food and health

Aims:

- **Aim 7:** Use of databases to analyse epidemiological data.

11.1 Antibody production and vaccination	
Applications and skills: • Application: Smallpox was the first infectious disease of humans to have been eradicated by vaccination. • Application: Monoclonal antibodies to HCG are used in pregnancy test kits. • Application: Antigens on the surface of red blood cells stimulate antibody production in a person with a different blood group. • Skill: Analysis of epidemiological data related to vaccination programmes. **Guidance:** • Limit the immune response to mammals.	

Essential idea: The roles of the musculoskeletal system are movement, support and protection.

11.2 Movement	
Nature of science: Developments in scientific research follow improvements in apparatus—fluorescent calcium ions have been used to study the cyclic interactions in muscle contraction. (1.8)	
Understandings: • Bones and exoskeletons provide anchorage for muscles and act as levers. • Synovial joints allow certain movements but not others. • Movement of the body requires muscles to work in antagonistic pairs. • Skeletal muscle fibres are multinucleate and contain specialized endoplasmic reticulum. • Muscle fibres contain many myofibrils. • Each myofibril is made up of contractile sarcomeres. • The contraction of the skeletal muscle is achieved by the sliding of actin and myosin filaments. • ATP hydrolysis and cross bridge formation are necessary for the filaments to slide. • Calcium ions and the proteins tropomyosin and troponin control muscle contractions. **Applications and skills:** • Application: Antagonistic pairs of muscles in an insect leg. • Skill: Annotation of a diagram of the human elbow. • Skill: Drawing labelled diagrams of the structure of a sarcomere. • Skill: Analysis of electron micrographs to find the state of contraction of muscle fibres.	**Aims:** • **Aim 7:** Use of grip strength data loggers to assess muscle fatigue. • **Aim 7:** Use of animations to visualize contraction.

11.2 Movement	
Guidance: • Elbow diagram should include cartilage, synovial fluid, joint capsule, named bones and named antagonistic muscles. • Drawing labelled diagrams of the structure of a sarcomere should include Z lines, actin filaments, myosin filaments with heads, and the resultant light and dark bands. • Measurement of the length of sarcomeres will require calibration of the eyepiece scale of the microscope.	

Essential idea: All animals excrete nitrogenous waste products and some animals also balance water and solute concentrations.

11.3 The kidney and osmoregulation

Nature of science:

Curiosity about particular phenomena—investigations were carried out to determine how desert animals prevent water loss in their wastes. (1.5)

Understandings:

- Animals are either osmoregulators or osmoconformers.
- The Malpighian tubule system in insects and the kidney carry out osmoregulation and removal of nitrogenous wastes.
- The composition of blood in the renal artery is different from that in the renal vein.
- The ultrastructure of the glomerulus and Bowman's capsule facilitate ultrafiltration.
- The proximal convoluted tubule selectively reabsorbs useful substances by active transport.
- The loop of Henle maintains hypertonic conditions in the medulla.
- ADH controls reabsorption of water in the collecting duct.
- The length of the loop of Henle is positively correlated with the need for water conservation in animals.
- The type of nitrogenous waste in animals is correlated with evolutionary history and habitat.

Applications and skills:

- Application: Consequences of dehydration and overhydration.
- Application: Treatment of kidney failure by hemodialysis or kidney transplant.
- Application: Blood cells, glucose, proteins and drugs are detected in urinary tests.
- Skill: Drawing and labelling a diagram of the human kidney.
- Skill: Annotation of diagrams of the nephron.

Utilization:

- The removal of kidney stones by ultra sound treatment.

Syllabus and cross-curricular links:
Biology
Topic 1.3 Membrane structure
Topic 1.4 Membrane transport

11.3 The kidney and osmoregulation	
Guidance: • ADH will be used in preference to vasopressin. • The diagram of the nephron should include glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henle, distal convoluted tubule; the relationship between the nephron and the collecting duct should be included.	

Essential idea: Sexual reproduction involves the development and fusion of haploid gametes.

11.4 Sexual reproduction

Nature of science:

Assessing risks and benefits associated with scientific research—the risks to human male fertility were not adequately assessed before steroids related to progesterone and estrogen were released into the environment as a result of the use of the female contraceptive pill. (4.8)

Understandings:

- Spermatogenesis and oogenesis both involve mitosis, cell growth, two divisions of meiosis and differentiation.
- Processes in spermatogenesis and oogenesis result in different numbers of gametes with different amounts of cytoplasm.
- Fertilization in animals can be internal or external.
- Fertilization involves mechanisms that prevent polyspermy.
- Implantation of the blastocyst in the endometrium is essential for the continuation of pregnancy.
- HCG stimulates the ovary to secrete progesterone during early pregnancy.
- The placenta facilitates the exchange of materials between the mother and fetus.
- Estrogen and progesterone are secreted by the placenta once it has formed.
- Birth is mediated by positive feedback involving estrogen and oxytocin.

Applications and skills:

- Application: The average 38-week pregnancy in humans can be positioned on a graph showing the correlation between animal size and the development of the young at birth for other mammals.
- Skill: Annotation of diagrams of seminiferous tubule and ovary to show the stages of gametogenesis.
- Skill: Annotation of diagrams of mature sperm and egg to indicate functions.

Guidance:

- Fertilization involves the acrosome reaction, fusion of the plasma membrane of the egg and sperm and the cortical reaction.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 3.3 Meiosis
Topic 6.6 Hormones, homeostasis and reproduction

Aims:

- **Aim 8:** Disputes over the responsibility for frozen human embryos.

Core topics

Essential idea: A balanced diet is essential to human health.

D.1 Human nutrition

Nature of science:

Falsification of theories with one theory being superseded by another—scurvy was thought to be specific to humans, because attempts to induce the symptoms in laboratory rats and mice were entirely unsuccessful. (1.9)

Understandings:

- Essential nutrients cannot be synthesized by the body, therefore they have to be included in the diet.
- Dietary minerals are essential chemical elements.
- Vitamins are chemically diverse carbon compounds that cannot be synthesized by the body.
- Some fatty acids and some amino acids are essential.
- Lack of essential amino acids affects the production of proteins.
- Malnutrition may be caused by a deficiency, imbalance or excess of nutrients in the diet.
- Appetite is controlled by a centre in the hypothalamus.
- Overweight individuals are more likely to suffer hypertension and type II diabetes.
- Starvation can lead to breakdown of body tissue.

Applications and skills:

- Application: Production of ascorbic acid by some mammals, but not others that need a dietary supply.
- Application: Cause and treatment of phenylketonuria (PKU).

International-mindedness:

- The Vitamin and Mineral Nutrition Information System (VMNIS), formerly known as the Micronutrient Deficiency Information System (MDIS), was established in 1991 following a request by the World Health Assembly to strengthen surveillance of micronutrient deficiencies at the global level.

Theory of knowledge:

- There are positive effects of exposure to sun such as the production of Vitamin D as well as health risks associated with exposure to UV rays. How can conflicting knowledge claims be balanced?

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 6.1 Digestion and absorption
Geography
Part 2F The geography of food and health
Chemistry
Topic B5 Vitamins

D.1 Human nutrition	
• Application: Lack of Vitamin D or calcium can affect bone mineralization and cause rickets or osteomalacia. • Application: Breakdown of heart muscle due to anorexia. • Application: Cholesterol in blood as an indicator of the risk of coronary heart disease. • Skill: Determination of the energy content of food by combustion. • Skill: Use of databases of nutritional content of foods and software to calculate intakes of essential nutrients from a daily diet.	

Essential idea: Digestion is controlled by nervous and hormonal mechanisms.

D.2 Digestion

Nature of science:

Serendipity and scientific discoveries—the role of gastric acid in digestion was established by William Beaumont while observing the process of digestion in an open wound caused by gunshot. (1.4)

Understandings:

- Nervous and hormonal mechanisms control the secretion of digestive juices.
- Exocrine glands secrete to the surface of the body or the lumen of the gut.
- The volume and content of gastric secretions are controlled by nervous and hormonal mechanisms.
- Acid conditions in the stomach favour some hydrolysis reactions and help to control pathogens in ingested food.
- The structure of cells of the epithelium of the villi is adapted to the absorption of food.
- The rate of transit of materials through the large intestine is positively correlated with their fibre content.
- Materials not absorbed are egested.

Applications and skills:

- Application: The reduction of stomach acid secretion by proton pump inhibitor drugs.
- Application: Dehydration due to cholera toxin.
- Application: *Helicobacter pylori* infection as a cause of stomach ulcers.
- Skill: Identification of exocrine gland cells that secrete digestive juices and villus epithelium cells that absorb digested foods from electron micrographs.

Guidance:

- Adaptations of villus epithelial cells include microvilli and mitochondria.

Utilization:

Syllabus and cross-curricular links:
Biology
Topic 1.2 Ultrastructure of cells
Topic 6.5 Neurons and synapses
Chemistry
Topic D4 pH regulation of stomach

Essential idea: The chemical composition of the blood is regulated by the liver.

D.3 Functions of the liver	
Nature of science: Educating the public on scientific claims—scientific studies have shown that high-density lipoprotein could be considered "good" cholesterol. (5.2)	
Understandings: • The liver removes toxins from the blood and detoxifies them. • Components of red blood cells are recycled by the liver. • The breakdown of erythrocytes starts with phagocytosis of red blood cells by Kupffer cells. • Iron is carried to the bone marrow to produce hemoglobin in new red blood cells. • Surplus cholesterol is converted to bile salts. • Endoplasmic reticulum and Golgi apparatus in hepatocytes produce plasma proteins. • The liver intercepts blood from the gut to regulate nutrient levels. • Some nutrients in excess can be stored in the liver. **Applications and skills:** • Application: Causes and consequences of jaundice. • Application: Dual blood supply to the liver and differences between sinusoids and capillaries.	**Theory of knowledge:** • Excessive alcohol consumption may cause liver cirrhosis. Are attitudes to drugs and alcohol an example of something that is relative to culture? Is all knowledge dependent on culture? **Aims:** • **Aim 6:** Temporary mounts of hepatocytes can be prepared from fresh liver. • **Aim 8:** Given the pressure on health resources, especially the availability of organs for transplant, should an alcoholic be allowed a liver transplant?

Essential idea: Internal and external factors influence heart function.

D.4 The heart

Nature of science:

Developments in scientific research followed improvements in apparatus or instrumentation—the invention of the stethoscope led to improved knowledge of the workings of the heart. (1.8)

Understandings:

- Structure of cardiac muscle cells allows propagation of stimuli through the heart wall.
- Signals from the sinoatrial node that cause contraction cannot pass directly from atria to ventricles.
- There is a delay between the arrival and passing on of a stimulus at the atrioventricular node.
- This delay allows time for atrial systole before the atrioventricular valves close.
- Conducting fibres ensure coordinated contraction of the entire ventricle wall.
- Normal heart sounds are caused by the atrioventricular valves and semilunar valves closing causing changes in blood flow.

Applications and skills:

- Application: Use of artificial pacemakers to regulate the heart rate.
- Application: Use of defibrillation to treat life-threatening cardiac conditions.
- Application: Causes and consequences of hypertension and thrombosis.
- Skill: Measurement and interpretation of the heart rate under different conditions.
- Skill: Interpretation of systolic and diastolic blood pressure measurements.
- Skill: Mapping of the cardiac cycle to a normal ECG trace.
- Skill: Analysis of epidemiological data relating to the incidence of coronary heart disease.

Guidance:

- Include branching and intercalated discs in structure of cardiac muscle.

Theory of knowledge:

- Symbols are used as a form of non-verbal communication. Why is the heart used as a symbol for love? What is the importance of symbols in different areas of knowledge?

Additional higher level topics

Essential idea: Hormones are not secreted at a uniform rate and exert their effect at low concentrations.

D.5 Hormones and metabolism

Nature of science:

Cooperation and collaboration between groups of scientists—the International Council for the Control of Iodine Deficiency Disorders includes a number of scientists who work to eliminate the harm done by iodine deficiency. (4.3)

Understandings:

- Endocrine glands secrete hormones directly into the bloodstream.
- Steroid hormones bind to receptor proteins in the cytoplasm of the target cell to form a receptor–hormone complex.
- The receptor–hormone complex promotes the transcription of specific genes.
- Peptide hormones bind to receptors in the plasma membrane of the target cell.
- Binding of hormones to membrane receptors activates a cascade mediated by a second messenger inside the cell.
- The hypothalamus controls hormone secretion by the anterior and posterior lobes of the pituitary gland.
- Hormones secreted by the pituitary control growth, developmental changes, reproduction and homeostasis.

Applications and skills:

- Application: Some athletes take growth hormones to build muscles.
- Application: Control of milk secretion by oxytocin and prolactin.

Aims:

- **Aim 8:** There are numerous drugs that can enhance performance. Is the use of these drugs acceptable in terms of conducting a fair test as long as all athletes have equal access to them?

Essential idea: Red blood cells are vital in the transport of respiratory gases.

D.6 Transport of respiratory gases

Nature of science:

Scientists have a role in informing the public—scientific research has led to a change in public perception of smoking. (5.1)

Understandings:

- Oxygen dissociation curves show the affinity of hemoglobin for oxygen.
- Carbon dioxide is carried in solution and bound to hemoglobin in the blood.
- Carbon dioxide is transformed in red blood cells into hydrogencarbonate ions.
- The Bohr shift explains the increased release of oxygen by hemoglobin in respiring tissues.
- Chemoreceptors are sensitive to changes in blood pH.
- The rate of ventilation is controlled by the respiratory control centre in the medulla oblongata.
- During exercise the rate of ventilation changes in response to the amount of CO_2 in the blood.
- Fetal hemoglobin is different from adult hemoglobin allowing the transfer of oxygen in the placenta onto the fetal hemoglobin.

Applications and skills:

- Application: Consequences of high altitude for gas exchange.
- Application: pH of blood is regulated to stay within the narrow range of 7.35 to 7.45.
- Application: Causes and treatments of emphysema.
- Skill: Analysis of dissociation curves for hemoglobin and myoglobin.
- Skill: Identification of pneumocytes, capillary endothelium cells and blood cells in light micrographs and electron micrographs of lung tissue.

Utilization:

- Training camps for athletes are frequently located at high altitude to increase the hemoglobin content of the blood. This puts the athlete at an advantage when they return to lower ground for competition.

Syllabus and cross-curricular links:
Biology
Topic 6.4 Gas exchange
Physics
Topic 3.2 Modelling a gas

Aims:

- **Aim 8:** Some sports, such as high-altitude mountain climbing or scuba diving, may push the limits of the human body beyond endurance and cause damage. Should they be controlled or banned?