Science

Biology

Rationale and aims

Rationale

The senior secondary Biology curriculum encompasses the three interrelated areas of science inquiry skills (incorporating skills and understanding of science as a way of knowing and doing), science as a human endeavour (incorporating knowledge and understanding of the personal, social, environmental, cultural and historical significance and relevance of science), and science understanding (incorporating knowledge and understanding of the biological, chemical, physical, and earth and space sciences). Building on students' science knowledge and skills acquired up to Year 10, the senior secondary Biology curriculum examines the development and latest applications of biological knowledge in ways which are relevant to students' everyday lives, and which enable them to solve problems and make evidence-based decisions related to present and future challenges. Biology encompasses many specialisations and interdisciplinary fields to explore how life exists, evolves and survives. It spans many organisational levels, from the functioning of whole organisms and their interrelationships, to the nature of cells and macromolecular systems. Biological fields include proteomics, metabolomics, ecology, physiology, biochemistry and genetics. New insights into the understanding of biological phenomena may also be provided by work in the physical sciences, geology, chemistry, mathematics and bioinformatics. By studying the senior secondary Biology curriculum, students appreciate both the changing and expanding body of contemporary knowledge in biology, and the study of biology as an independent and collaborative human endeavour.

Aims

The aim of the senior secondary Biology curriculum is to provide students with a solid foundation in science knowledge, understanding, skills and values on which further learning and adult life can be built. Students should be able to:

- draw on their curiosity and willingness to speculate about and explore the world to expand their interest in biology
- plan and undertake practical and other research investigations involving collection, collation and analysis of qualitative and quantitative data, interpretation of experimental outcomes and the use of models and simulations to visualise, explore and explain events
- engage in communication of and about biology, value evidence and scepticism, and evaluate critically the scientific claims made by others
- solve problems, and make informed, responsible and ethical decisions when considering local and global issues and applications of biological concepts, techniques and technologies in daily life
- appreciate biology as both an independent and a collaborative human endeavour
- develop in-depth knowledge, understanding, skills and scientific values relating to biology
- appreciate the changing and expanding body of contemporary knowledge in biology.

Organisation

Content structure

The senior secondary Biology curriculum is organised around three interrelated strands: *Science inquiry skills*, *Science as a human endeavour*, and *Science understanding*.

Science inquiry skills

Scientific inquiry involves posing questions; formulating testable hypotheses; planning, conducting and critiquing investigations; collecting, analysing and interpreting evidence; and communicating findings. This strand is concerned with investigating ideas, evaluating claims, solving problems, drawing valid conclusions and developing evidence-based arguments. It also recognises that scientific explanations change as new or different evidence becomes available.

Science as a human endeavour

Science influences society through posing and responding to social and ethical issues, and science research is influenced by societal challenges or social priorities. This strand highlights the need for informed, evidence-based decision-making about current and future applications of science. It acknowledges that, in making decisions about science and its practices, moral, ethical and social implications must be taken into account. This strand also acknowledges that science has been advanced through, and is open to, the contributions of many different people from different cultures at different times in history. It identifies the historical aspects of science as well as contemporary scientific issues and activities and that science offers rewarding career paths.

Science understanding

An understanding of science is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict phenomena, and applies that knowledge to new situations and events. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established over time and that continue to be challenged and refined by scientists. Science knowledge represents the building blocks of science understanding, but it is the dynamic nature of science understanding and applications that will benefit citizens in an ever-changing world.

Links to K-10

The senior secondary Biology curriculum builds on the knowledge and skills developed by students in science up to the end of Year 10 and extends their learning in the K–10 biological, physical and earth sciences. The three organisational strands in Science K-–10, *Science understanding*, *Science as a human endeavour* and *Science inquiry skills,* are continued into the senior secondary Biology curriculum. As with the Years K–10 science course, it is expected that teachers are able to show connections across these three strands in the exploration of biological ideas, concepts and principles. The inquiry approach to science fostered throughout Years K–10 is strengthened in the senior secondary years, with students formulating hypotheses generated from their own questions, and investigating and reporting on these. They also undertake an extended experimental investigation to explore an aspect of biology in depth.

Pathways

The senior secondary Biology curriculum provides pathways for students wishing to pursue further studies or those wishing to enter the workforce. While students may choose to specialise in biology, synergies between the four senior science courses provide opportunities for students to pursue multidisciplinary areas of science in addition to studying specific concepts through different discipline lenses. Concurrent study of *Biology* and *Chemistry* enhances students' understanding of various biochemical processes, for example enzyme function, bioenergetics and pharmaceutical development. Concurrent study of *Biology* and *Earth and Environmental Science* enables students to evaluate evidence for varying scientific viewpoints and theories, and enhances their decision-making capacity related to issues of local concern, for example monitoring environmental change, species extinction and evolution. Concurrent study of *Biology* and *Physics* may stimulate students' interest in astrobiology and nuclear medicine.

In addition to providing pathways for further study or employment, the senior secondary Biology curriculum provides opportunities for all students to develop an understanding of biological concepts and principles which will enable them to become more informed citizens who are able to make evidence-based decisions about the science-related issues which arise in their lives.

Unit structure

Content of the senior secondary Biology curriculum is outlined below.

Unit 1: Cells and the functioning organism

In this unit, students will use an inquiry approach to investigate and develop their understanding of the structure and function of cells, and the role of cellular functioning in enabling organisms to grow and survive.

This will include the study of: cells as the basic units of life, including their chemical nature and the movement of substances across plasma membranes; the cell cycle; the structural, functional and behavioural adaptations that enhance an organism's survival; and the use of biotechnologies to enhance reproductive processes and repair lost functioning.

Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 2: Change and survival

In this unit, students will use an inquiry approach to investigate and develop their understanding of changes in ecosystems and the survival of organisms.

This will include the study of: the dynamics of ecosystems; methods of monitoring environmental factors and populations; population dynamics; biological evolution and natural selection; the evolution of Australian flora and fauna; implications of human intervention in evolutionary processes; and human evolution.

Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 3: Cells and systems in action

In this unit, students will use an inquiry approach to investigate and develop their understanding of the physiological and biochemical responses of cells and biological systems to stimuli.

This will include the study of: detection and response to signals in the environment; regulation and control in plants; regulation and control by the nervous system; regulation and control by the endocrine system; human defence mechanisms; human intervention in functioning of the immune system; disorders of the immune system; regulation of biochemical processes by enzymes; and the energy economy of cells.

Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 4: Heredity and change

In this unit, students will use an inquiry approach to investigate and develop their understanding of heredity and change.

This will include the study of: the cell-to-cell transmission of genetic information by nuclear division; gene expression and regulation; genetic variation; prediction of mating outcomes; the nature and application of DNA manipulation tools and techniques; and the use of molecular homology in providing evidence for relatedness between species.

Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

General capabilities

The Australian Curriculum, Assessment and Reporting Authority (ACARA) has identified 10 general capabilities that will be specifically covered in the curriculum. In the senior secondary Biology curriculum, eight of these are considered inherent to science and so are explicitly included in the content descriptions and achievement standards. These are literacy, numeracy, information and communication technologies (ICT), thinking skills, creativity, teamwork, ethical behaviour and self-management. Each of these is embedded in the content descriptions of the *Science inquiry skills* strand and many are also incorporated into the *Science as a human endeavour* strand.

Literacy is an important capability in biology. Students will be taught how to use and interpret the language of biology, including specific terminology and correct representation of visual texts. They will be required to communicate their knowledge within and beyond the biology community, selecting and using formats appropriate to a purpose and audience, including written texts, multimodal representations and oral presentations. They will access, critically read, and extract information related to biology from a variety of sources, and acknowledge these sources appropriately.

Numeracy knowledge and skills are used and developed within the biology course in a range of situations, often through the measurement and analysis of results from investigations and field work. Both qualitative and quantitative data will be collected and represented in appropriate formats. Students will be required to analyse numerical and graphical data in a range of situations which could include, for example, measuring the rates of osmosis, determining the relationships between growth and pH or salinity, and analysing quadrat data from field studies. Students will apply the concept of error and uncertainty to their results and will evaluate the reliability of measurements in first- and second-hand data. They will be required to use skills of statistical analysis when using data from both their own experiments and from secondary sources.

Information and communication technologies (ICT) are relevant to teaching and learning in a large part of the senior secondary Biology curriculum. This will include the use of the internet to research concepts and applications as well as the use of digital learning objects such as animations and simulations to enhance students' understanding and engagement in biology. The use of the internet and local networks will facilitate a collaborative approach among students that models the methods of modern science. In practical investigations, ICT will aid students in tasks such as data collection and analysis through the use of hardware such as temperature probes, pH meters, dissolved oxygen sensors and the use of spreadsheet software. This enables students to use and analyse results efficiently, allowing for the development of valid conclusions, and also allows access to other potential areas for investigation. Simulations and modelling using digital technologies provide students with opportunities to experience situations which cannot be investigated through practical experiments in the classroom, especially in the area of molecular pathways and genetics. ICT offers opportunities to provide a range of media for communicating and sharing students' ideas and understandings both within and beyond the classroom.

Thinking skills are integral to the development of understanding in biology, including the ability to pose questions, make predictions, speculate, solve problems through investigation, make evidence-based decisions, analyse and evaluate evidence from their own and others' work and summarise information. Students will be encouraged to plan and conduct practical investigations as well as to select appropriate information from secondary sources and to evaluate the sources of information used to formulate conclusions. Students will also develop skills to evaluate claims based on the biological sciences, for example in the media and in advertising.

Creativity enables the development of ideas that are new to the individual. Students will develop skills that enable them to formulate creative questions, speculate, think in new ways about observations of the world around them and suggest solutions to biologically-based problems. In this course some of the students' understandings of the world around them will be taken to a deeper level, involving the development and amendment of existing understandings. Students will be encouraged to be flexible and open-minded as their own understandings of biological concepts change and develop. Creative approaches to problem-solving may also be applied when students are required to perform experiments using new methodologies or limited resources. For example, they may be required to develop equipment that allows them to keep two different sizes of tadpoles separated within one aquarium without unduly impeding water flow.

Self-management is intrinsic to the ability to effectively carry out experiments and investigations. Specific self-management skills will be developed as students are encouraged to plan effectively for individual, collaborative, online and fieldwork activities, and when they reflect on their own practices and learning. In this course the degree of guidance given to students will be reduced when compared with that experienced in earlier stages of schooling, requiring that students work as independent learners.

Teamwork is an important aspect of science at a number of levels, both personal and organisational. At times students will be required to work together, sharing ideas and discussing and debating their work in order to develop and consolidate their knowledge. They will study examples of biologists working in teams, both harmoniously and discordantly, to develop biological ideas or products, or undertake research in a specific branch of biology. The focus in this course will be on developing harmonious, collaborative methods of student inquiry in their own learning and for future work applications.

Ethical behaviour is considered in relation to both experimental science and the acquisition and use of scientific information, including when working independently, in teams or in an online environment. In carrying out investigations students are encouraged to gather evidence honestly and ethically, considering the implications of the investigation. This is especially important when dealing with living organisms, and students will consider the reasons for guidelines and regulations relating to practical work with animals. They will also consider the importance of minimising environmental impact during field studies and consider alternative investigative methods based on ethical issues relating to the effect on living organisms being studied. Students will also develop skills to evaluate claims based on science. This will enable them to make more valid judgments about social, environmental and personal issues that involve biology. There will also be opportunities for students to discuss the ethical implications of applications of biology in areas such as medical interventions in immunisation and reproductive technologies, conservation of biodiversity, genetic engineering and the use of natural resources.

Cross-curriculum dimensions

The cross-curriculum dimension of sustainability is addressed in the content descriptions of the senior secondary Biology curriculum. Knowledge and understanding of the natural environment is incorporated within the content descriptions for the *Science understanding* strand. It includes conservation of natural resources such as water and forests; the diversity of plants and animals; susceptibility to disease; and the interdependence of organisms within ecosystems. Sustainability as a social and environmental issue is incorporated in the *Science as a human endeavour* strand in areas such as the effects of climate change on evolution, biodiversity, ecosystems, energy production and water management; land use; waste treatment; bioremediation; and use of genetics in regeneration of extinct species. Important skills associated with sustainability, including researching areas such as the management of plants and animals and evaluating claims and arguing ideas, are incorporated within the *Science inquiry skills* strand.

Curriculum content that relates to Indigenous history and culture is represented in the content descriptions of the senior secondary Biology curriculum. The *Science as a human endeavour* strand explicitly includes the effects over time of practices of Indigenous peoples on biodiversity and sustainability of populations and ecosystems. The relationship between the land and Indigenous peoples over time is implicit in the *Science understanding* strand through the study of human-induced changes in environmental conditions, including strategies for maintaining ecological and habitat diversity.

The cross-curriculum perspective of Asia provides engaging and rich contexts for science learning.

Unit 1 - Cells and the functioning organism

In this unit, students will use an inquiry approach to investigate and develop their understanding of the structure and function of cells, and the role of cellular functioning in enabling organisms to grow and survive. This will include the study of: cells as the basic units of life, including their chemical nature and the movement of substances across plasma membranes; the cell cycle; the structural, functional and behavioural adaptations that enhance an organism's survival; and the use of biotechnologies to enhance reproductive processes and repair lost functioning. Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

The cell as the basic structural unit of life, including:

• structures and organelles of prokaryotic and eukaryotic cells (cell membrane, cell wall, nucleus, chloroplast, ribosome, vacuole, flagellum, endoplasmic reticulum, Golgi apparatus, cytoskeleton and mitochondrion)

• similarities and differences between prokaryotic and eukaryotic cells

• the facilitation of cellular function by organelles in eukaryotic cells.

The chemical nature of the cell, including:

• the unique properties of water that make it essential to life

• the chemical structure and cellular function of biomolecules, including carbohydrates, lipids, proteins and nucleic acids

• the role of ions and vitamins in cell functioning.

Cell cycle, including:

• cell division for growth and for repair of tissues

• significance of mitosis in the transmission of hereditary material

• replication of DNA

• the visible changes and movement of chromosomes during mitosis

• cytokinesis in plant and animal cells

• cell differentiation and development

• mitotic division in binary fission of bacteria.

The movement of substances across the plasma membrane to maintain the functioning cell, including:

- cells as systems with inputs and outputs
- movement of materials within and between cells of multicellular organisms, and between cells and their environment
- characteristics of cell membranes as efficient surfaces of exchange, including the significance of the relationship between surface area and volume
- simple and facilitated diffusion
- osmosis
- active transport
- endocytosis, pinocytosis and exocytosis
- function of desmosomes and plasmodesmata.

Structural, functional and behavioural adaptations that enhance an organism's survival, including:

- environmental factors and challenges that affect the way organisms meet their requirements for life, including obtaining nutrients, water and gases; disposal of wastes; shelter; and protection
- adaptations of unicellular and multicellular organisms to terrestrial and aquatic habitats
- interaction of structural, functional and behavioural adaptations of organisms for thermal and osmotic regulation in different conditions
- adaptations of organisms for survival in extreme climatic conditions.

The use of biotechnologies to enhance reproductive processes and restore or repair lost functioning, including:

- the purpose of intervention in animal (including humans) and plant reproduction
- technologies, techniques and procedures used to intervene in animal and plant reproductive processes (for example, the contraceptive pill, IVF, surrogacy, cloning, artificial pollination, fertility control in pest populations)
- the nature of currently used prostheses with examples of situations in which they may be used (for example, artificial limbs, joint replacements, the cochlear ear)
- organ or tissue transplants and the ethical and medical considerations involved in their use (for example, the source of cells to grow potential skin transplants, the source of organs for transplantation, mechanisms to determine supply to patients needing transplants, the problems created by rejection of transplanted tissue)
- the implanting of stimuli-producing devices and their interaction with the nervous system (for example, pacemakers).

Science as a human endeavour

The nature and practice of biology, including:

- the dynamic nature of the body of biological knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• the change in the nature of biology over time which has given rise to emerging fields of study relying on interdisciplinary perspectives (for example, systems biology, sociobiology, molecular biology) and the development of technologies (for example, new types of microscopes)

• the cellular basis of life and that all life is intrinsically unique and interconnected, and that all species are adapted to their environment, face limits to population size and are subjected to change

• ethical issues, principles and guidelines related to the contemporary work of biologists

• the value of insightful observations and the critical questioning of established paradigms (for example, the impact of the discovery of prions and retroviruses on the understanding of information flow from the nucleus to cytoplasm)

• the use of the knowledge of cells or the functioning organism in careers such as medicine, veterinary science, agriculture, marine studies and pharmacy

• the diversity of fields of study in biology as career options, and the relevance of biological knowledge in everyday life and non-science career pathways.

Contemporary research and applications of biology, including:

• the interdisciplinary nature of contemporary applications of biology (for example, drug design, proteomics, tissue culture, bioinformatics), many of which depend on an understanding of chemistry, mathematics, computer science or physics in addition to biology

• social and ethical issues raised by the application of animal (including human) and plant reproductive technologies

• the application of knowledge in a field of biology to contemporary research in other fields (for example, the development of technologies to search for life on other planets as informed by knowledge about cells adapted for survival in extreme habitats on earth).

The development of ideas in biology, including:

• changes in ideas and knowledge in biology through technological advances that have affected human lives (for example, the development of new medical interventions; artificial organs or limbs)

• the development of the cell theory of life from the time of Anton van Leeuwenhoek to the understanding of the role of telomeres in the cell cycle through the research of Elizabeth Blackburn and colleagues

• the Watson/Crick discovery of DNA structure (using models built of cardboard held by clamps and retort stands) building on the work of Rosalind Franklin’s X-ray crystallography

• historical stories detailing biologists’ resilience, self belief and strength of character to argue the case against a prevailing paradigm based on accurate data collection and scientific evidence (for example, William Harvey and blood circulation).

Science inquiry skills

Design and perform investigations and experiments related to cells and the functioning organism, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• measuring and collecting data about cell organelles in order to identify organelles and to suggest functions of their component parts

• identifying organelles and deducing relationships between them from second-hand data such as micrographs

• investigating and comparing plant and animal cells and relating various cell types to their functions within the organism

• investigating the requirements for root growth to facilitate mitotic division at the root tip

• investigating cell division (mitosis) at various locations in an onion or garlic root tip

• modelling mitosis, diffusion or osmosis using a variety of tools (for example, claymation or physical models) to demonstrate conceptual understanding of the steps involved in the process

• predicting and exploring reactions of single-celled organisms (for example, Amoeba, Euglena, Paramecium) and simple organisms (e.g. Hydra, copepods) to various concentration gradients (glucose, salt), pH or temperature conditions

• investigating the response of pollen to a range of salt and sugar solutions and relating this to changing micro- and macro-environmental conditions in the carpel

• investigating the response of seeds to a range of environmental conditions and relating this to adaptability to changing environmental conditions

• investigating and comparing the process of osmosis in plant and animal cells

• modelling binary fission in bacteria to explain colony growth on an agar plate

• investigating the surface-area-to-volume ratio, rate of diffusion and concentration gradient of a plant tissue such as potato or beetroot in various concentrations of salt or sugar

• constructing models of cells including organelles, either physically or electronically, to demonstrate conceptual understanding of relative size and function.

Develop skills in performing investigations and experiments, including:

• using observations of the living world to generate questions and guide the construction of hypotheses that inform the design of investigations

• selecting and safely using appropriate equipment for the task (for example, data loggers, video cameras, light microscopes, measuring devices, dissection equipment)

• collecting and recording first- and second-hand data using appropriate formats and ICT (for example, labelled scale scientific drawings, digital photographs of cells)

• locating and selecting relevant and reliable second-hand data

• comparing experimental results with quantitative predictions (for example, the data from student experiments in diffusion and osmosis compared with data presented in secondary sources)

• formulating explanations and conclusions based on experimental evidence

• evaluating methods employed in investigations and suggesting specific changes to improve the reliability and validity of results of students' own experimental investigations or of any investigations described in secondary sources

• evaluating methods employed in investigations and suggesting specific changes to improve the accuracy of results.

Engage in critical, creative, innovative and reflective thinking, including:

• evaluating the validity of varying scientific results and scientific arguments

• proposing new questions for investigation and innovative solutions to problems related to cells and functioning organisms

• generating ideas, plans, processes or products, including using ICT where appropriate, to solve problems or to challenge current thinking

• inquiring into ethical and social issues related to cells and the functioning organism (for example, 'Should unicellular organisms be considered as animals and be protected by ethical guidelines similar to guidelines for invertebrates?', 'Is experimentation using animals justified if the research may save thousands of animal or human lives?')

• reflecting on individual learning progress and processes with consideration of preferred learning styles and previous misconceptions, explaining how and why their ideas have changed

• testing ideas, identifying the strengths and weaknesses of ideas, and recognising better ideas

• applying techniques to solve problems and for the generation of innovative ideas and alternative applications of technology (for example, 'thinking outside the square', suspending disbelief to consider how the functions of cellular organelles could be altered or improved).

Analyse and synthesise information relating to biology, including:

• researching and synthesising information from a range of sources

• interpreting three-dimensional structure and relationships of organelles from two-dimensional images

• using and interpreting models and simulations to aid understanding and communication of biological concepts (for example, mitosis, differences between diffusion and osmosis)

• evaluating the scientific accuracy of claims in advertising and the media

• using evidence as the primary criterion for decisions about the validity of suggested ideas and arguments.

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing methods, conclusions and explanations

• creating and presenting structured reports of experimental and investigative work, using ICT where appropriate

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security

• discussing results and findings with others in order to develop understanding

• using correct biological representations, including use of appropriately labelled scientific drawings with scale measurements and explanatory captions

• evaluating methodologies and evidence

• explaining concepts and debating issues related to cells and functioning organisms.

Unit 2 - Change and survival

In this unit, students will use an inquiry approach to investigate and develop their understanding of changes in ecosystems and the survival of organisms. This will include the study of: the dynamics of ecosystems; methods of monitoring environmental factors and populations; population dynamics; biological evolution and natural selection; the evolution of Australian flora and fauna; implications of human intervention in evolutionary processes; and human evolution. Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Dynamics of ecosystems, including:

• the cyclic nature of matter (including carbon, nitrogen and water) in an ecosystem

• trophic levels and feeding relationships, including producers, consumers of differing orders, decomposers

• the relationships between organisms, including predation, competition, symbiosis and commensalism

• energy pathways in ecosystems (food chains and food webs)

• pyramids of energy, biomass and numbers.

Methods of monitoring environmental factors and populations, including:

• instruments used to monitor environmental conditions (for example, measurement of temperature, air pressure, humidity, wind speed, pH, nutrient levels, weather)

• sampling techniques to quantify species, population numbers, density and abundance, and distribution patterns, including species count in quadrats or along a transect line, trapping, aerial survey, capture/recapture techniques

• remote sensing technologies (for example, for detection of mineral deposits; mapping of land cover features such as vegetation, soil, water and differing vegetation types).

Population dynamics, including:

• factors which affect biodiversity and sustainability (for example, natural climate change, global warming, migration, pollution, practices of Indigenous peoples and settlers, current agricultural and logging practices) and the nature of their effects

• a selected Australian case study that demonstrates the effect of change on biodiversity and sustainability of an ecosystem (for example, cane toads, feral cats, the Chytrid fungus on native frog populations).

Biological evolution and natural selection, including:

• preconditions for natural selection, including diversity within a population (variation), environmental change, selection pressures and time (successive generations)

• evidence of evolution derived from the fossil record

• contemporary examples of natural selection (for example, the development of resistance of pathogens to drugs; development of resistance to agrochemicals in a plant pest)

• evidence of extinction of species derived from both the fossil record and the present

• relationships between natural selection, biodiversity and environmental stability.

Evolution of Australian flora and fauna, including:

• significant events in Australia's geological history and their effect on the evolution of a unique flora and fauna

• the effect of change in past climates on Australia's flora and fauna

• the effect of past and current human activity on Indigenous flora and fauna

• explanation of global patterns of biogeography by plate tectonics (for example, the distribution of marsupials and Proteaceae worldwide, the delineation of Asian and Wallacean species by the Wallace line, overlay of localised geological features by species clades)

• current trends in environmental change and the effects on Australia's biodiversity.

Implications of human intervention in evolutionary processes, including:

• selective breeding, domestication of animals and plants, and cloning of agricultural plants and animals

• medical intervention in sustaining life to reproductive age

• environmental management techniques that affect survival of selected species (for example, weed and pest control)

• human activities which may change the selection pressures to which organisms are exposed (for example, pollution of air, water or land; alteration of habitat for different purposes; harvesting food organisms).

Human evolution, including:

• alternative scientific hypotheses about human origins, dispersal and evolution due to differences in interpretation and weighting of evidence of fossils and artefacts

• members of the genus Homo and their evolutionary antecedents

• the influence of current research and discoveries on ideas about the evolution of humans

• the interaction of biological, cultural and technological evolution on human evolution

• human activities which may change the selection pressures to which humans are exposed.

Science as a human endeavour

The nature and practice of biology, including:

• the dynamic nature of the body of biological knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• the interdisciplinary nature of contemporary applications of biology (for example, bioarchaeology, conservation biology, palaeontology, population ecology) many of which depend on chemistry, mathematics, computer science and physics in addition to biology

• ethical issues, principles and guidelines related to the contemporary work of biologists

• the importance of sharing knowledge and skills between collaborating people working in a range of scientific disciplines when collecting and considering data to support arguments about biodiversity and sustainability of communities and ecosystems

• the ethics of decisions which advantage one life form at the expense of another and the ethics of human intervention to 'control' population (for example, eradicating undesirable feral organisms, breeding for desired pedigrees in domestic species).

Contemporary research and applications of biology, including:

• the application of knowledge about natural selection and evolution to solving the problem of the build-up of resistance to drugs or agrochemicals in disease-causing organisms or the design of conservation projects to maintain biodiversity and/or prevent extinction

• issues that may arise when applying relevant scientific understanding to plans to deal with contemporary sustainability issues (for example, energy production and use; water management; land use for agriculture, logging, residential or recreational purposes; exploitation of living and mineral resources, when there are conflicts with economic and social or cultural concerns of the people involved in plan development).

The impact of evidence on changing ideas in biology, including:

• a comparison of the ideas of Lamarck and Darwin on the mechanism controlling change of characteristics in populations and the impact of new evidence on the development of these theories

• the acceptance of Darwin's theories and celebration of his scientific contribution after his death

• the people and discoveries involved in changes in understanding about the processes of evolution, including hominid evolution.

Science inquiry skills

Design and perform investigations, experiments and fieldwork related to change and survival, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• undertaking a field study of a local ecosystem (for example, creek, riparian system, cliff face with different rock types, reserve with known differential fire history) to generate and analyse data on a variety of physical and biological components

• investigating local population variation of a single species (for example, snail shell patterns; spots on lily flowers; variations in colour of violas, cane toads, black/white plumage of magpies)

• investigating fish or tadpole body shape as a variation with stream turbulence

• investigating the effects of selective pressure by modelling (for example, data related to survival generated by using weighted dice)

• investigating brain size in a variety of hominids by making models or by using commercial models

• investigating relationships between species by making models of bone shape and length from a variety of mammals or hominids or by using commercial models

• investigating the impact of pollution or human settlement on population numbers or biodiversity of a region

• investigating the effects of an environmental change (for example, temperature, pH, salinity) by comparing growth rates of plants/animals in response to the change.

Develop skills in performing investigations, experiments and fieldwork, including :

• using biological concepts to guide the formulation of hypotheses which may be tested in fieldwork, investigations and experiments

• selecting and using appropriate scientific equipment and techniques for specific observational and measurement tasks in fieldwork and experiments

• using mathematical and graphical methods to analyse quantitative data related to contemporary issues of sustainability such as data from the students' fieldwork, investigations and experiments, laboratory work or from secondary sources

• locating and selecting relevant and reliable second-hand data

• evaluating methods employed in investigations and suggesting specific changes to improve the reliability and validity of results

• formulating explanations based on first-hand data

• working ethically when undertaking investigations and collaborative research with others.

Engage in critical, creative, innovative and reflective thinking, including:

• evaluating the validity of their own and other scientific arguments

• applying knowledge of biology to solve problems and to understand and predict solutions to problems of survival related to change

• proposing new questions for investigation and innovative solutions to problems related to change and survival

• generating ideas, plans, processes or products, including using ICT where appropriate, to solve problems or to challenge current thinking

• reflecting on their learning progress and any previous misconceptions that have been addressed

• testing their ideas, identifying the strengths and weaknesses of their ideas, and recognising better ideas

• reflecting on changes in their attitude or behaviours as a result of learning progress

• debating issues related to change and survival (for example, 'Should endangered species be preserved in captivity?').

Analyse and synthesise information relating to biology, including:

• evaluating claims in advertising and the media (for example, campaign material from environmental action groups such as Greenpeace in the campaign to stop whaling; property developers, government departments and QUANGOs and the dilemma about human population explosions and housing versus environmental impact; media reports of discoveries related to hominid evolution)

• researching and synthesising information from a range of sources

• discussing alternative theories of evolution and migration with consideration of the appropriate data and evidence required to support claims.

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing hypotheses, proposals, procedures, results, conclusions and explanations

• creating and presenting information in a range of communication formats (for example, structured reports of experiments, investigations or field work; seminars; ICT-rich presentations)

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security

• discussing ethical considerations, results and findings of investigations with others in order to develop and clarify understanding

• using and interpreting models and simulations to aid understanding and communication of biological concepts (for example, devising computer animations, simulations or claymations to demonstrate natural selection)

• explaining concepts and debating issues related to change and survival.

Unit 3 - Cells and systems in action

In this unit, students will use an inquiry approach to investigate and develop their understanding of the physiological and biochemical responses of cells and biological systems to stimuli. This will include the study of: detection and response to signals in the environment; regulation and control in plants; regulation and control by the nervous system; regulation and control by the endocrine system; human defence mechanisms; human intervention in functioning of the immune system; disorders of the immune system; regulation of biochemical processes by enzymes; and the energy economy of cells. Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Detection and response to signals in the environment, including:

• stimuli (for example, temperature, water, concentration of dissolved substances such as nutrients and gases, touch, presence of other organisms) in the internal and external environments of organisms that are detected by interoceptors and exteroceptors

• stimulus–response model, including positive and negative feedback

• the role of homeostasis in maintaining a relatively constant internal environment for optimal functioning (for example, temperature regulation, water balance, blood glucose balance).

Plant responses to stimuli, including:

• stomatal responses to variations in water, light and carbon dioxide concentrations

• plant growth regulators (auxins, gibberellins, cytokinins and abscisic acid)

• growth responses to directional stimuli, including light, gravity and mechanical pressure

• nastic responses to non-directional stimuli, including light intensity, touch and chemical stimuli

• growth responses due to factors including lack of water, high salinity, mineral deficiencies and soil pH, which limit photosynthesis and other plant metabolic processes

• the role of bushfires in stimulating plant growth.

Regulation and control by the nervous system, including:

• the structure of nerve cells and neural pathways

• receptors and sense organs

• the central nervous system and major regions of the human brain

• biochemistry of neural cell stimuli transmission

• interaction between the nervous system and other body systems to enable a coordinated response to stimuli (for example, links between the muscular and endocrine systems in producing the ‘fight-flight’ response to fright)

• consequences of psychoactive drugs (both legal and illegal) that can lead to addiction.

Regulation and control by the endocrine system, including:

• hormones and pheromones as chemical signalling molecules

• interaction of the endocrine and circulatory systems in the transmission of hormones

• detection of specific hormones by receptors of target cells

• the role of hormonal responses in helping coordinate body systems, growth and reproductive cycles

• a selected example of a hormone involved in responding to internal and external environmental change (for example, insulin and blood glucose levels) and the response.

Human defence mechanisms, including:

• the nature and source of non-self antigens

• physical barriers that keep pathogens from entering the body (for example, the cough reflex, enzymes in tears and skin oils, mucus, skin, stomach acid)

• components of the innate immune response and their actions including the inflammatory response

• components and actions of the adaptive immune response, including clonal selection and the production of antibodies, and the role of antigen presenting cells in antigen recognition

• the role of the lymphatic system in the adaptive immune response.

Human intervention in the functioning of the immune system, including:

• the distinction between active and passive immunity

• the nature of antigens in vaccines, including dead or attenuated pathogens, toxins, protein fragments from the pathogen and other currently experimental agents

• steps in the preparation of an effective vaccine

• the response of the immune system to vaccination, including the action of T and B lymphocytes

• the biological rationale for booster shots.

Diseases of the immune system, including:

• the nature of the disease in cases classified as immunodeficiency, autoimmunity and hypersensitivity.

• the symptoms and treatment of an example of an immune disease.

Regulation of biochemical processes by enzymes, including:

• structure and function of enzymes, including cofactors, the role of active sites, and substrate specificity

• the stepwise, enzyme-catalysed nature of the chemical reactions of cells

• the 'lock and key' and 'induced fit' models for enzyme action

• factors affecting the rate of catalytic activity of enzymes (temperature, pH, concentration of reactants and products, and inhibitors)

• examples of the main categories of digestive enzymes and their function

• examples of disruption to chemical pathways in the absence or denaturing of enzymes (for example, phenylketonuria (PKU)).

The energy economy of cells, including:

• the importance of glucose as a fuel molecule for cells

• the reactants and products of aerobic and anaerobic cellular respiration in plants and animals represented in words and as chemical equations

• the differences between aerobic and anaerobic respiration in terms of the molecules involved in the reaction pathway and the energy released

• locations where the steps in the overall respiration reaction occur

• uses by the body, tissues and cells of plants and animals of the energy released in respiration

• the reactants and products of photosynthesis represented in words and as chemical equations

• the steps and molecules involved in photosynthesis, including details of the light and dark reactions

• adaptations to photosynthesis in C3, C4 and CAM plants

• locations within the plant cell where the steps in the synthesis of glucose occur

• the fate of glucose produced in photosynthesis.

Science as a human endeavour

The nature and practice of biology, including:

• the dynamic nature of the body of biological knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• the interdisciplinary nature of contemporary applications of biology (for example, bioinformatics, molecular medicine, oncological research, tissue culture) many of which depend on chemistry, mathematics, computer science and physics in addition to biology

• ethical issues, principles and guidelines related to the contemporary work of biologists

• identification of a range of careers in which a person may use knowledge of the nervous or endocrine systems or of enzyme function (for example, medicine, drug design and mental health)

• application of the understanding of plant growth factors and responses to stimuli in a variety of careers (for example, horticulture, agriculture).

Contemporary research and applications of biology, including:

• current research into the relationships between accidental head injuries and the functions of various areas of the brain

• arguments for and against mass immunisation programs, especially those currently in place for immunisation of young children

• application of knowledge about the human immune system to develop treatment for AIDS, food allergies, asthma, transplant rejection, or autoimmune diseases (for example, coeliac and Crohn’s diseases, Type 1 diabetes, lupus, multiple sclerosis)

• application of understanding of the variations in the photosynthetic pathways to develop plants to suit extreme environmental conditions (for example, extremes of hot or cold, flood or drought, extended periods of light or dark) or to the production of enzyme-specific herbicides

• the development of biofuels.

The development of ideas in biology and the global impact of Australian biomedical research, including:

• the history of disease causation and how ideas have changed over time as data and new evidence challenge the prevailing paradigm

• the development of vaccines and their biological and social consequences, including the work of Edward Jenner and the subsequent eradication of smallpox, and Ian Fraser’s HPV vaccine for cervical cancer

• the global impact of the work of Australian scientists, including McFarlane Burnet, Peter Doherty, Don Metcalfe and Barry Marshall on fighting disease

• historical experiments and human stories related to investigations in cellular function which demonstrate application of scientific values and endeavour.

Science inquiry skills

Design and perform investigations and experiments related to cells in action, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• examining a recent outbreak of an infectious disease (plant or animal) and modelling its spread within populations.

• investigating the effects of plant hormones at different concentrations or the rate of a reaction under the control of an enzyme (for example, catalase)

• investigating reactions under various conditions (for example, temperatures, pH, concentrations of enzyme, inhibitors)

• investigating the effect of environmental factors on photosynthesis or stomatal aperture (for example, carbon dioxide concentrations, temperature, light intensity, light quality)

• investigating the effect of mineral deficiencies or toxicities on plant growth rate and the appearance of deficiency symptoms (for example, chlorosis, necrosis)

• investigating factors affecting anaerobic respiration through breadmaking, yoghurt making, wine making

• investigating the biochemistry involved in the production of biofuels

• experimenting with differing concentrations of pheromones used as a means of insect control (for example Codling moth in apple crops, controlling ant movement with dilute formic acid).

Develop skills in performing investigations and experiments, including:

• using biochemical concepts and models to develop testable hypotheses

• selecting and using the most appropriate methods for a specific task in order to minimise experimental error, including the use of digital technology to record data where appropriate

• integrating some understanding of statistics (for example, means, treatment of error) when analysing data from their own experiments or data in reports used to gather information (for example, reports of immunisation programs, treatments of disease, the development of plants to survive in extreme conditions)

• evaluating primary and secondary data in terms of the methods used to collect the data

• formulating evidence-based explanations and relating these to biological concepts

• comparing the validity of alternative explanations based on experimental results when considering the outcomes of their experiments or when exploring contemporary issues or applications of biology

• working ethically both as a collaborative team member and as an independent self-managing learner.

Engage in critical, creative, innovative and reflective thinking, including:

• contributing evidence-based opinions and information to discussions about issues involving biology (for example, the cost/benefit of research into biofuels or diseases of plants and humans)

• debating ethical and social issues related to biology (for example, ‘Should immunisation programs be mandated in order to protect society?’ ‘Who should pay for immunisation programs?’)

• analysing the accuracy of arguments presented by various stakeholders about the merits of vaccination, distinguishing between fact and opinion

• justifying ideas for future investigation in areas such as treatment of disease, immunisation or management of plants and animals

• generating ideas, plans, processes or products, including using ICT where appropriate, to solve problems or to challenge current thinking

• reflecting on individual learning progress and processes with consideration of preferred learning styles and addressing of previous misconceptions

• reflecting on the role of the scientist as the self-experimenter (or risk taker) in the fight against disease.

Analyse and synthesise information relating to biology, including:

• researching and synthesising information from a range of sources, and commenting on the validity of the information sources in terms of its origin and provision of supporting data

• formulating evidence-based explanations and relating these to scientific concepts (for example, when drawing conclusions about the benefit of childhood vaccination).

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing methods, conclusions and explanations

• creating and presenting structured reports of experimental and investigative work, including using ICT where appropriate, and making a public presentation of findings

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security

• using models and simulations to organise, explain and communicate biological concepts (for example, biochemical pathways, the mechanism for enzyme action, natural and acquired immune responses).

Unit 4 - Heredity and change

In this unit, students will use an inquiry approach to investigate and develop their understanding of heredity and change. This will include the study of: the cell-to-cell transmission of genetic information by nuclear division; gene expression and regulation; genetic variation; prediction of mating outcomes; the nature and application of DNA manipulation tools and techniques; and the use of molecular homology in providing evidence for relatedness between species. Students will reflect on how knowledge in biology in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Cell-to-cell transmission of genetic information by nuclear division, including:

• key stages in, and functions of, mitosis and meiosis

• the main steps in DNA replication

• the division of the nucleus in eukaryotic cells

• chromosome behaviour in both mitosis and meiosis, and events including crossing over, random assortment and non-disjunction that increase genetic variability in the offspring of sexually reproducing organisms

• the advantages of sexual reproduction in terms of genetic variability in offspring compared with asexual reproduction

• significance of the haploid state in exposing deleterious genes (for example, sex-linked diseases in humans, haploid sexes in social insects, evolution rates in bacteria)

• cloning and the nature of stem cells

• cell cycle malfunctions that lead to cancerous cells

• apoptosis.

Gene expression and regulation, including:

• the nature of genes and genomes

• the genetic code and why it is degenerate

• production of the mRNA transcript and processing by spliceosomes

• roles of tRNA and rRNA (ribosomes) in translating a nucleotide sequence into an amino acid sequence

• polypeptide synthesis and the secretory pathway of protein products from the cell

• the importance of proteins and their functional diversity

• the need for gene expression to be regulated using a prokaryotic model (the lac operon)

• the impact of other molecules on gene expression that leads to phenotypic complexity (for example, epigenetics).

Genetic variation, including:

• types of mutations, including point mutations, as a base change in the DNA sequence, and the possible consequences on cell metabolism

• causes of mutations, including random changes and mutagens such as chemicals or radiation

• mutations as a source of new alleles that may be advantageous, deleterious or neutral

• the consequences of changing allele frequencies in a population (gene pool) through selection pressures, gene flow and genetic drift (founder effect and bottleneck)

• lack of genetic variability as a factor in increasing the chance of extinction

• examples of genetic diseases of humans caused by mutations, including in mtDNA.

Prediction of mating outcomes, including:

• patterns of Mendelian inheritance

• use of Punnett squares to predict outcomes in monohybrid and dihybrid crosses

• use of predicted outcomes of matings in genetic counselling, including issues that arise from cytoplasmic gene transfer (for example, mitochondrial genes)

• the effects of non-random mating, mutations, selection, limited population size, random genetic drift and gene flow on population gene pools

• Hardy-Weinberg principle and equation.

The nature and application of DNA manipulation tools and techniques, including:

• cutting and pasting DNA using endonucleases and ligases to produce recombinant DNA

• the role of vectors, including plasmids, in transforming bacterial cells

• the polymerase chain reaction (PCR) technique to copy a DNA sequence

• gel electrophoresis as a technique to sort out different sized fragments of DNA and its application in DNA profiling (using STRs)

• the difference between genetically modified and transgenic organisms.

The use of molecular homology in providing evidence for relatedness between species, including:

• the nature of scientific evidence for biological evolution using DNA sequences, including mitochondrial DNA studies, amino acid sequences and comparative genomics

• comparison of biological data from different species, using bioinformatic tools to construct phylogenetic trees to depict relatedness over time

• human evolution from hominoids to hominins and mtDNA studies to map human evolution and the migration out of Africa.

Science as a human endeavour

The nature and practice of biology, including:

• the dynamic nature of the body of biological knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• the interdisciplinary nature of contemporary applications of biology (for example, genomics, proteomics, metabolomics, molecular evolution, cadistics), many of which depend on chemistry, mathematics, computer science, physics, nanotechnology and bioinformatics in addition to biology

• ethical issues, principles and guidelines related to the contemporary work of biologists

• the contributions of people working in a range of scientific disciplines, such as anthropology, botany, zoology, genetics and geology, to the development of knowledge about the nature and sequence of evolution.

Contemporary research and applications of biology, including:

• applications of genetic engineering in production of drugs and vaccines, treating disease, gene targeting, decomposition of wastes, bioremediation or recreating an extinct species

• ethical and moral stances related to the application of techniques of genetic manipulation in plants and animals, including humans, for such purposes as to increase crop yield, to increase nutritional value of foods, or to develop treatments for debilitating illnesses.

The development of ideas in biology, including:

• stories of the learning journey followed by significant researchers and their work to change understanding of heredity, the changing view of genetics and the development of genetic engineering techniques (for example, cracking the genetic code, Kary Mullis and PCR, Craig Venter's work in sequencing the human genome)

• consideration of differing historical, ethical and social perspectives related to the use of biotechnology techniques for commercial or medical purposes (for example, phenomics, genetic profiling, production of cell lines using embryonic stem cells, production of genetically modified food products, the development of transgenic organisms)

• historical experiments and human stories related to investigations in genetics which demonstrate application of scientific values and endeavour

• consideration of the place of our contemporary biological knowledge in future scenarios (for example, the potential for RNAi technology to deliver allergen-free food and selectively manipulate nutrients such as amino acids in crops, development of synthetic genomes).

Science inquiry skills

Design and perform investigations and experiments related to heredity and change, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• conducting a breeding experiment with a rapidly reproducing organism, such as fruit flies, fast plants or zebra finches, and comparing the actual ratios of offspring phenotypes with predicted values

• investigating social insect species that have haploid sex forms (for example, honey bees, termites)

• investigating aspects of heredity and genetics by predicting cross-breeding outcomes using Punnett squares and computer simulations

• investigating the mode of inheritance (for example, whole chromosome/gene, autosomal/X-linked, dominant/recessive/co-dominant) of different inherited conditions

• extracting DNA from plants (for example, wheat germ, strawberries)

• investigating DNA fingerprinting and DNA profiling using interactives and simulations available from the internet (for example, forensic mysteries, paternity cases, use of STR data from close relatives to create a genetic profile of a missing person)

• investigating DNA evidence by preparing DNA for electrophoresis and running DNA through an acrylamide gel

• using karyotyping to investigate inherited conditions (for example, Klinefelter's syndrome XXY, Turner's syndrome X).

Develop skills in performing investigations and experiments, including:

• drawing Punnet squares to predict genotypes and phenotypes of matings

• drawing pedigree charts to illustrate inheritance

• evaluating primary and secondary data in terms of the methods used to collect the data

• formulating evidence-based explanations and relating these to genetic concepts

• using sterile techniques to produce genetically modified bacteria (for example, using one of the many commercially available kits)

• loading samples on to a gel and managing the process of electrophoresis

• reading and interpreting a DNA fingerprint gel

• working ethically both as a collaborative team member and as an independent self-managing learner.

Engage in critical, creative, innovative and reflective thinking, including:

• developing arguments showing consideration of ethical, social and economic aspects of a situation (for example, the use of advanced forensic technologies to convict criminals of crimes committed many years earlier)

• contributing evidence-based opinions and information to discussions about contemporary aspects and issues in biology

• justifying ideas for future genetics investigations

• generating ideas, plans, processes or products, including using ICT where appropriate, to solve problems or to challenge current thinking

• reflecting on individual learning progress and processes with consideration to preferred learning styles and previous misconceptions

• testing their own and others' ideas, identifying the strengths and weaknesses of their own and others' ideas, recognising better ideas and knowing when to abandon an idea

• investigating and discussing the ethical and social issues related to genetics (for example, cloning, gene manipulation technologies, genetic testing, DNA profiling, other genomics issues)

• considering the social consequences of genetic testing or genetic manipulation of human DNA

• examining the justification of ownership over scientific information (for example, intellectual property laws, plant variety rights).

Analyse and synthesise information relating to biology, including:

• researching and synthesising information relating to genetics from a range of sources

• commenting on the validity of information sources in terms of origin and provision of supporting data

• comparing the validity of alternative explanations based on experimental results.

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing methods, conclusions and explanations

• creating and presenting structured reports of experimental and investigative work, including appropriate use of ICT and making a public presentation of findings

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security

• using models, flow charts or digital simulations to organise, explain and communicate genetic concepts (for example, meiosis; non-disjunction; DNA replication; protein synthesis; processes of genetic manipulation; human genetic diseases caused by base substitutions, deletions or inversions)

• justifying arguments (for example, in Socratic discussion or in debate) on controversial topics related to genetics (for example, Today's biotechnology solutions are tomorrow's environmental problems or deciding 'Did Y-chromosome Adam and mitochondrial Eve ever meet?').