Biology

Subject Outline
Stage 1 and Stage 2

Version 1.0 – Draft for Online Consultation
Ref: A496768
15 February 2016 – 30 March 2016

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INTRODUCTION

SUBJECT DESCRIPTION

Biology may be undertaken as a 10-credit subject or a 20-credit subject at Stage 1 and as a 20-credit subject at Stage 2.

The study of biology develops an understanding of the diversity of life as it has evolved, the structure and function of living things, and how they interact with other members of their own species, other species, and their environments. By investigating biological systems and their interactions, from microscopic cellular structures and processes to macroscopic ecosystem dynamics, students develop knowledge and understanding that enable them to explore and explain everyday observations and find solutions to biological issues. In Biology, students appreciate the significance of the work of classical and modern biologists and develop knowledge and skills that enable them to join in and initiate debates about how biology impacts on their lives, society, and the environment.

The study of biology enables students to develop the skills and understanding needed to explain biological phenomena and to draw evidence-based conclusions from investigations of biology-related issues and innovations. Through their exploration of science as a human endeavour, students increase their understanding of the complex ways in which science interacts with society. They use their understanding of the interconnectedness of biological systems to evaluate the impact of human activity. They explore strategies and possible solutions to address major biological challenges now and in the future, in local, national, and global contexts.

Students develop a range of understandings and inquiry skills that encourage and inspire them in thinking scientifically, and pursuing future pathways, including medical, veterinary, food and marine sciences, agriculture, biotechnology, environmental rehabilitation, biosecurity, quarantine, conservation and ecotourism.

CAPABILITIES

The capabilities connect student learning within and across subjects in a range of contexts. They include essential knowledge and skills that enable people to act in effective and successful ways.

The SACE identifies seven capabilities. They are:

- literacy
- numeracy
- information and communication technology capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students develop their literacy capability by, for example:

- critically analysing and evaluating primary and secondary data
- extracting biological information presented in a variety of modes
- using a range of communication formats to express ideas logically and fluently, incorporating the terminology and conventions of biology
- synthesising evidence-based arguments
- using appropriate structures to communicate for specific purposes and audiences.

Numeracy

In this subject students develop their numeracy capability by, for example:

- measuring with appropriate instruments
- recording, collating, representing, and analysing primary data
- accessing and investigating secondary data
- identifying and interpreting trends and relationships
- calculating and predicting values by manipulating data and using appropriate scientific conventions.

Information and communication technology capability

In this subject students develop their information and communication capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- communicating biological ideas, processes, and information
- understanding the impact of ICT on the development of biology and its application in society
- evaluating the application of ICT to advance understanding and investigations in biology.

Critical and creative thinking

In this subject students develop critical and creative thinking by, for example:

- constructing, reviewing, and revising hypotheses to design related investigations
- interpreting and evaluating data and procedures to develop logical conclusions
- analysing interpretations and claims, for validity and reliability
- devising imaginative solutions and making reasonable predictions
- envisaging consequences and speculating on possible outcomes
- recognising the significance of creative thinking on the development of biological knowledge and applications.

Personal and social capability

In this subject students develop their personal and social capability by, for example:

- understanding the importance of biological knowledge on health and well-being, both personally and globally
- making decisions and taking initiative while working independently and collaboratively
- planning effectively, managing time, following procedures effectively, and working safely
- sharing and discussing ideas about biological issues, developments, and innovations while respecting the perspectives of others
- recognising the role of their own beliefs and attitudes in gauging the impact of biology in society.

Ethical understanding

In this subject students develop their ethical understanding by, for example:

- considering the implications of their investigations on organisms and the environment
- making ethical decisions based on an understanding of biological principles
- acknowledging the need to plan for the future and to protect and sustain the biosphere
- recognising the importance of their responsible participation in social, political, economic, and legal decision-making.

Intercultural understanding

In this subject students develop their intercultural understanding by, for example:

- recognising that science is a global endeavour with significant contributions from diverse cultures
- respecting different cultural views and customs while valuing scientific evidence
- being open-minded and receptive to change in the light of scientific thinking based on new information
- understanding that the progress of biology influences and is influenced by cultural factors.

ABORIGINAL AND TORRES STRAIT ISLANDER KNOWLEDGE, CULTURES, AND PERSPECTIVES

In partnership with Aboriginal and Torres Strait Islander communities, and schools and school sectors, the SACE Board of South Australia supports the development of

high-quality learning and assessment design that respects the diverse knowledge, cultures, and perspectives of Indigenous Australians.

The SACE Board encourages teachers to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design, delivery, and assessment of teaching and learning programs by:

- providing opportunities in SACE subjects for students to learn about Aboriginal and Torres Strait Islander histories, cultures, and contemporary experiences
- recognising and respecting the significant contribution of Aboriginal and Torres Strait Islander peoples to Australian society
- drawing students' attention to the value of Aboriginal and Torres Strait Islander knowledge and perspectives from the past and the present
- promoting the use of culturally appropriate protocols when engaging with and learning from Aboriginal and Torres Strait Islander peoples and communities.

HEALTH AND SAFETY

The handling of live animals, pathogens, and a range of chemicals and equipment requires appropriate health, safety, and welfare procedures.

It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2012*, in addition to relevant state, territory, or national health and safety guidelines. Information about these procedures is available from the school sectors.

The following safety practices must be observed in all laboratory work:

- Use equipment only under the direction and supervision of a teacher or other qualified person.
- Follow safety procedures when preparing or manipulating apparatus.
- Use appropriate safety gear when preparing or manipulating apparatus.

Any teaching activities that involve the care and use of, or interaction with, animals must comply with the *Australian code of practice for the care and use of animals for scientific purposes 8th edition*, in addition to relevant state or territory guidelines.

Keeping live animals in an educational setting requires permission from the relevant Animal Ethics Committee. Permission to dissect animals must be obtained in writing from these committees.

For Department of Education and Child Development schools, information can be obtained from the DECD Fact Sheets web page (www.sustainableschools.sa.edu.au/pages/Fact_sheets/).

The Non Government Schools Animal Ethics Committee is a collaboration between Catholic Education South Australia and the Association of Independent Schools of South Australia (www.ais.sa.edu.au/home/general-information/animal-ethics).

Stage 1 Biology

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 1 Biology.

In this subject, students are expected to:

1. use science inquiry skills to design and conduct biological investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, and analyse the results of biological investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. demonstrate and apply knowledge and understanding of biological concepts in new and familiar contexts
5. demonstrate understanding of science as a human endeavour
6. communicate knowledge and understanding of biological concepts, using appropriate terms, conventions, and representations.

CONTENT

Stage 1 Biology may be undertaken as a 10-credit or a 20-credit subject.

Science inquiry skills and science as a human endeavour are integral to students' learning in this subject and are interwoven through their study of science understanding, which is organised into four topics. Through the study of these topics, students develop and extend their understanding of the nature of living things, as well as of the interactions of those living things with members of the same species, members of other species, and the environment.

Using an inquiry approach to learning through observation, speculation, prediction, experimentation, analysis, evaluation, and communication, students develop and extend their science inquiry skills and reinforce their understanding of science as a human endeavour.

The science inquiry skills and the understanding of science as a human endeavour that can be developed through practical and other learning activities in each topic are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections that follow.

Programming

Stage 1 Biology consists of the following topics:

- Topic 1: Cells and Microorganisms
- Topic 2: Infectious Disease
- Topic 3: Multicellular Organisms
- Topic 4: Biodiversity and Ecosystem Dynamics

For a 10-credit subject, students study two of these topics.

For a 20-credit subject, students study all four topics.

Topics can be studied in their entirety or in part, taking into account student interests and preparation for pathways into future study of biology.

Science Inquiry Skills and *Science as a Human Endeavour* must be integrated into both 10-credit and 20-credit programs.

Stage 1 Biology students who intend to study Biology at Stage 2 would benefit from a Stage 1 program that includes Topic 1: Cells and Microorganisms.

Note that the topics are not necessarily designed to be of equivalent length – it is anticipated that teachers may allocate more time to some than others.

The topics selected can be sequenced and structured to suit individual cohorts of students.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

 indicates a possible teaching and learning strategy

 indicates a possible activity to develop Science Inquiry Skills

 indicates a possible Science as a Human Endeavour context

An inquiry-based approach is integral to the development of science understanding. The *Possible Strategies, Contexts, and Activities* column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop and extend their knowledge, skills, and understanding.

Science Inquiry Skills

In Biology investigation is an integral part of the learning and understanding of concepts, by using scientific methods to test ideas and develop new knowledge.

Practical investigations involve a range of individual and collaborative activities during which students develop and extend the science inquiry skills described in the table that follows.

Practical activities may take a range of forms, such as developing models and simulations that enable students to develop a better understanding of particular concepts. They include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students display and analyse the data they have collected, evaluate procedures, describe their limitations, consider explanations for their observations, and present and justify conclusions appropriate to the initial question or hypothesis.

For a 10-credit subject, it is recommended that 8–10 hours of class time would involve practical activities.

For a 20-credit subject, it is recommended that 16–20 hours of class time would involve practical activities.

Science inquiry skills are also fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically analyse the evidence they obtain so that they can present and justify a conclusion.

Science inquiry skills are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop and extend student understanding of science inquiry skills. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	**Possible Strategies, Contexts, and Activities**
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – a hypothesis or inquiry question – types of variables ➢ dependent ➢ independent ➢ factors held constant (how and why they are controlled) ➢ factors that may not be able to be controlled (and why not) – materials required – the procedure to be followed – the type and amount of data to be collected – identification of ethical and safety considerations.	Class activities to develop skills could include: – designing investigations without implementation – changing an independent variable in a given procedure and adapting the method – researching, developing, and trialling a method – improving an existing procedure – identifying options for measuring the dependent variable – researching hazards related to the use and disposal of chemicals and/or biological materials – developing safety audits – identifying relevant ethical and/or legal considerations in different contexts.
Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. • Conduct investigations, including: – selection and safe use of appropriate materials, apparatus, and equipment – collection of appropriate primary and/or secondary data (numerical, visual, descriptive) – individual and collaborative work.	Class activities to develop skills could include: – identifying equipment, materials, or instruments fit for purpose – practising techniques and safe use of apparatus – comparing resolution of different measuring tools – distinguishing between and using primary and secondary data.
Results of investigations are presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including	Class activities to develop skills could include: – practising constructing tables to tabulate data, including column and row labels with units

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
– use of appropriate SI units, symbols – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	– identifying the appropriate representations to graph different data sets – selecting appropriate axes and scales to graph data – clarifying understanding of significant figures using, for example: www.astro.yale.edu/astro120/SigFig.pdf www.hccfl.edu/media/43516/sigfigs.pdf www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm – comparing data from different sources to describe as quantitative, qualitative.
Scientific information can be presented using different types of symbols and representations. • Select, use, and interpret appropriate representations, including: – mathematical relationships, such as ratios – diagrams – equations to explain concepts, solve problems and make predictions.	Class activities to develop skills could include: – writing chemical equations – drawing and labelling diagrams – recording images – constructing flow diagrams.
Analysis of the results of investigations allows them to be interpreted in a meaningful way. • Analyse data, including: – identification and discussion of trends, patterns, and relationships – interpolation/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent variables – using graphs from different sources, e.g. CSIRO or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity – reliability	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. www.biologyjunction.com/sample%20ap%20lab%20reports.htm

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
– effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions.	
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and bibliographies – opportunities to practise scientific communication in written, oral, and multimedia formats, e.g. presenting a podcast or writing a blog.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through the exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

3. Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, and environmental impacts, offer valid explanations, and make reliable predictions.

- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.

- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline, and the understandings should be integrated and used in a 10- credit or 20-credit program, as points of reference for student learning.

The  symbols in the right-hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Topic 1: Cells and Microorganisms

The cell is the basic unit of life. All cells possess some common features: all prokaryotic and eukaryotic cells need to exchange materials with their immediate external environment in order to maintain the chemical processes vital for cell functioning. In this topic, students examine the development of the cell theory, the exchange of materials, and processes required for cell survival. Students use the microscope and modelling to study the structure and function of cells, and investigate ways in which matter is recycled and energy is transformed and transferred in the biochemical processes of photosynthesis and respiration.

Many unicellular microorganisms cause disease in human beings, and others are used in science and industry. Students learn about the conditions necessary for the growth and survival of microorganisms, the uses of microorganisms, and their role in decomposition and food spoilage.

Science Understanding	Possible Strategies, Contexts, and Activities
Living things are distinguishable from non-living things.	Compare the characteristics of living things and non-living things.
The cell theory unifies all living things. Living things are made up of one or more cells. Cells: – are the structural and functional units of life – cells come from pre-existing cells – cells contain hereditary material. The cell is the smallest independent unit of life. The cell membrane defines a cell; it separates the cell from its surroundings.	Trace the understanding of cells through Robert Hooke's development of the compound microscope and examination of cork tissue. Refer to cell membrane: www.phet.colorado.edu/en/simulation/membrane-channels
The major cell types are: – prokaryotic – eukaryotic. Prokaryotic and eukaryotic cells have many features in common (a reflection of their common evolutionary past). These features include: – cell membrane – nucleic acids – proteins – ribosomes. Prokaryotic cells lack internal membrane-bound organelles, do not have a nucleus, are significantly smaller than eukaryotic cells, and usually have a single circular chromosome. • Compare the structure of prokaryotes and eukaryotes.	Briefly study the concept of organelles with some examples (nucleus, ribosome, vacuole, mitochondrion, chloroplast, endoplasmic reticulum, Golgi body). Use a microscope to observe cells by: – using prepared slides – making slides – using photomicrographs. Research: – Galileo – first primitive microscope – van Leeuwenhoek – discovered bacteria, protists.
In order to reproduce, cells need to copy their genetic material, and then divide to	Reinforce some of the differences between prokaryotic and eukaryotic

Science Understanding	Possible Strategies, Contexts, and Activities
form two new (daughter) cells. • Describe and represent binary fission in prokaryotic cells • Describe and represent mitosis • Compare binary fission with mitotic cell division in eukaryotic cells	cells, such as the number of chromosomes and their structure. Introduce the terms diploid and haploid. Microscopic observation of (plant) cells at different stages of cell division.
Cells require energy. The source(s) of energy are light (most autotrophs) and chemical (heterotrophs). Photosynthesis, respiration, and fermentation are important energy processes for cells. • Write word equations for photosynthesis, respiration, and fermentation (in plant and animal cells).	Investigate the presence of starch in leaves that have sections blocked from sunlight. Investigate fermentation of glucose by yeast to understand the factors that affect anaerobic respiration.
Cells require materials. • Compare the sources of materials for autotrophs and heterotrophs. Explain the need for removal of wastes.	Construct a table to show a comparison of heterotrophs and autotrophs.
Material requirements move in and wastes and some cell products move out of cells. The cell membrane separates cellular activity from the external environment. • Describe the structure of the semi-permeable cell membrane. The selectively permeable nature of the cell membrane maintains relatively constant internal conditions. • Explain how the cell membrane controls the exchange of materials between the cell and its environment. • Describe how some substances move passively across the cell membrane with the concentration gradient (i.e. by diffusion and osmosis). • Compare active and passive transport with regard to: – concentration gradient – energy requirement. The surface area-to-volume ratio of cells is critical to their survival.	Investigate the historical change in the understanding of cell membrane structure over time. Explain why composition and conditions inside the cell need to be maintained. Illustrate the effects of osmosis on cells. Other processes such as endocytosis and exocytosis may be discussed. Investigate diffusion using, for example, cellulose tubing, starch, and iodine solutions. Observe osmosis, for example in rhubarb epidermal cells. Model cell size and diffusion using agar cubes.
Cells use metabolic pathways. Enzymes are organic catalysts. An enzyme is specific to a particular substrate.	Briefly introduce enzyme-controlled reactions using examples, such as glycolysis. Investigate the effect of conditions such as temperature, pH on enzyme activity

Science Understanding	Possible Strategies, Contexts, and Activities
• Describe a metabolic pathway. • Describe the role of enzymes in metabolism.	to understand the functioning of enzymes. Explore enzyme-related diseases such as Phenylketonuria, G6PD Deficiency, Alkaptonuria. Research treatments using drugs that interact with enzymes, for example, penicillin or non-steroidal anti-inflammatory drugs, considering unexpected consequences or side effects.

Microorganisms are important living things.
Microorganisms include bacteria, fungi and protists.
In ideal conditions bacteria grow exponentially.
Different bacteria require specific conditions for growth.
• Discuss the effects of factors such as:
  – temperature
  – nutrient availability
  – moisture
  – pH
  – the removal of wastes.
Microorganisms act as decomposers, which enables recycling of essential nutrients.
Bacteria reproduce by binary fission (asexual).
	Safety considerations of any practicals using live organisms must be considered.
	Explain the role of microorganisms in the decomposition and recycling of matter.
	Test the growth of microbes on agar plates or other nutrient media.
	Investigate the effect of antibiotics and antiseptics on the growth of bacteria.
	Investigate the contribution to understanding by microbiologist such as Pasteur, Koch, or Jenner.
	Discuss the use and limitations (including overuse) of antibiotics.
	Discuss the efficacy of ‘natural’ remedies in controlling microorganisms.
	Investigate questions such as: Are claims on hand sanitisers accurate? e.g. ‘kills 99.9% of bacteria’.
	Debate the value or otherwise of probiotics.

Microorganisms are important to humans.
• Discuss the role of microorganisms in:
  - oxygen production by phytoplankton
  - decomposition of dead and waste materials recycles nutrients through the non-living environment
  - recombinant DNA technology.
Humans have cultured and used microorganisms for about 10 000 years.
	Discuss the role of phytoplankton and the importance of maintaining the health of the world’s oceans.
	Microorganisms and decomposition can be linked to biogeochemical cycles in Stage 1, Topic 4: Biodiversity and Ecosystem Dynamics.
	Discuss the importance of yeast from a historical perspective.
	Compare fermentation as an anaerobic alternative to respiration.
	Explore industrial examples of fermentation:
	  – bread making
	  – brewing
	  – wine-making

Science Understanding	Possible Strategies, Contexts, and Activities
	– cheese, yoghurt production – linen production (retting). Investigations could include making yoghurt, cheese, or bread and investigating the effects of different factors. Discuss innovations such as, the role of bacteria in genetic engineering of human growth hormone and/or human insulin. Discuss the historical uses of microbes as an example of biotechnology, for example, in fermentation and project their potential uses. Investigate the use of microbial enzymes in PCR in, for example, forensics.
Microorganisms can cause food spoilage and by controlling the growth of microorganisms, food can be preserved. • Describe the causes of food spoilage, and explain the importance of hygienic practices. • Describe techniques for preserving food, including the use of heat/cold, the addition of acids, sugars, or salt, and the removal of water. Relate each technique to growth requirements of microorganisms.	Discuss food preservation by: – limiting growth of microbes – destroying or preventing the entry of microbes. Investigate food spoilage under different conditions. Test factors affecting preservation of food (e.g. meat). Explore industrial examples of food preparation, storage, and preservation. Investigate spread of disease, such as salmonella, via food.

Topic 2: Infectious Disease

In this topic, students examine the various agents that can cause infectious diseases, including viral, bacterial, and other parasitic pathogens.

Students examine how infectious disease agents spread, enter hosts, and cause immune responses. They make comparisons to the function of immune systems in other organisms.

Students examine the structure and function of the main components of the immune system: physical barriers, the innate (non-specific) system, and the specific responses of the adaptive or acquired system. Students learn that pathogens cause changes that enable memory for future immune response.

Students study how biotechnology has contributed to not only the understanding of the human immune system but also the development of vaccinations and other medications.

There are various possibilities for students to look at the impact that infectious diseases have on populations across the global community, including factors that affect spread, control, and treatment of infectious disease.

Science Understanding	Possible Strategies, Contexts, and Activities
Infectious disease differs from other diseases. • Distinguish between infectious and non-infectious disease. • Determine the characteristics of a pathogen. • Describe the methods by which pathogens may be transmitted between hosts, such as: - air - dust - direct contact - faeces - food - animals.	**Safety considerations of any practicals using live organisms must be considered.** Use examples of infectious disease such influenza, hepatitis, whooping cough as a context for this topic. Compare infectious diseases with genetic and 'lifestyle' diseases. Describe different types of pathogens such as some bacteria, fungi, protists, viruses, prions, and other parasitic (e.g. parasitic worms) groups. Use malaria and/or influenza as examples of contagious pathogens that use animal hosts for transmission to humans. Examine adaptations in the lifecycles of parasites (e.g. hookworm or tapeworm). Investigate the structure and function of the different types of pathogens by: - using electron microscope diagrams to investigate size, scale, and structure of the pathogens - identifying bacterial cells. Use microscopes to examine specimens of various pathogens, including bacteria, fungi, and other parasites. Research pets as hosts of pathogens (e.g. dogs and worms, cats and toxoplasmosis).

Science Understanding	Possible Strategies, Contexts, and Activities
Infectious diseases can cause widespread health issues for local, national, and/or global populations. • Describe the interrelated factors that can determine the spread of infectious disease, including: – persistence of the pathogen within hosts – the transmission mechanism – the proportion of the population that is immune or has been immunised – mobility of individuals of the affected population. Examples of disease control include: – controlling the carriers (e.g. fleas, mosquitoes) – killing the pathogen (e.g. antibiotics, antiseptics) – quarantining carriers of the disease – the immune response.	Discuss factors that could cause an epidemic of an infectious disease (e.g. influenza, Ebola, Zika): – increased virulence – new antibiotic resistance – new toxins – natural genetic shift – herd immunity due to vaccination. Investigate, with the use of computer modelling, how infectious disease can become an epidemic or pandemic e.g. cholera. Useful websites include: www.shodor.org/interactivate/activities/SpreadofDisease/ www.asm.org/index.php/scientists-in-k-12-outreach/classroom-activities/23-education/k-12-teachers/8206-outbreak-investigating-epidemics www.ehsc.oregonstate.edu/files/ehsc7/John%20Snow%202.05.pdf Investigate the spread of infectious disease through populations, using simple practical exercises and models. Examine how epidemiologists test hypotheses to determine the most effective control measures, to prevent infectious disease spread. Use case studies from history and recent times to investigate epidemics and pandemics, for example Ebola, SARS, cholera or bubonic plague.)- Examine the factors involved in the spread and control of these outbreaks. Discuss the ethics of controlling the spread of disease by: - quarantine - access to medications/vaccines - considering the location of the outbreak. Evaluate strategies to control the spread of diseases. Strategies could include: - site planning - water supply - sanitation and hygiene - food supply - health education.
Pathogens have adaptations that facilitate their entry into cells and tissues and hosts. • Describe how pathogens and host	Discuss entry points for pathogens into the human body, including: – wounds

Science Understanding	Possible Strategies, Contexts, and Activities
cells recognise each other. • Explain that some pathogens enter cells to survive and reproduce. • Describe the basic concept of molecular recognition, e.g. pathogens binding to cellular receptors. • Explain that some pathogens must enter cells to ensure their survival replication, and to evade the immune system.	– respiratory surfaces – reproductive routes – digestive system. Study the concepts of DNA replication, transcription/translation, as many viruses take control of the infected cells through the replication/protein synthesis machinery). Investigate plant pathogens. These pathogens need to be controlled to prevent spread through Australia (or on a global scale). Examples include: *Phytophthora cinnamomi,* Potato spindle tuber viroid. Use animations to model the entry of viruses and other pathogens into cells. Useful website: www.highered.mheducation.com/sites/0072556781/student_view0/chapter18/animation_quiz_1.html
When a pathogen enters a host, it causes physical or chemical changes which stimulate immune responses in the host. • Define the term 'antigen'. • Compare foreign antigens (non-self) with self-antigens.	Discuss the role of Major Histocompatibility Complex in the presentation of antigens to the immune system. Note that foreign antigens and their molecular recognition is by – Antibody-antigen binding – MHC and complement. Compare the virulence/-contagiousness/transmissibility of different infectious agents (e.g. examine different strains of the same pathogen, such as. *E.coli* K12 compared to *E.coli* O157:H7 or HIV-1 compared to HIV-2.)
The human immune system protects the body against disease by: – physical barriers – innate (non-specific) immune response – the adaptive (acquired) immune response. These responses work together to neutralise or prevent entry of pathogens. • Describe the function of the various physical barriers that exist to prevent the entry of pathogens. • Many organisms have an innate (non-specific) immune system to the presence of pathogens. • Recognise that the innate (non-specific) immune system is the	Review the key entry points for microorganisms include the respiratory, digestive, and reproductive systems and wounds. Study physical barriers including: – the skin as the primary physical barrier – the human cough reflex – the cornea of the eye – enzymes in tears and skin oils – mucus which traps bacteria and small particles – stomach acid – earwax. Investigate the use of antiseptics and/or hand washes to enhance the

Science Understanding	Possible Strategies, Contexts, and Activities
second line of defence with responses that are non-specific. • Recognise that most organisms, including bacteria, fungi, plants, invertebrates and vertebrates display innate immune responses as a first line of defence against pathogens e.g. histamine, complement, antibiotics etc. • Describe how the adaptive (acquired) immune response responds specifically to antigens. • Describe how the human body responds specifically to foreign antigens via the adaptive (acquired) immune system.	effectiveness of physical barriers. Describe the function of the components of the innate (non-specific) immune system, including: – complement system – inflammatory response – phagocytes – natural Killer Cells. Describe the function of the components of the adaptive immune response, including: – B-lymphocytes – T-lymphocytes – antibodies – memory cells – secondary lymphoid organs. Compare the difference between the innate (non-specific) and adaptive immune systems. This can be explained by the role of memory cells. Use an example to describe how the immune system responds to and defends against different types of pathogens (e.g. virus: HIV, herpes, influenza and bacteria: *Streptococcus pnuemoniae, Helicobacter pylori*).
Exposure to an antigen is required for acquired immunity. This may be acquired through passive or active processes. Passive immunity may be acquired from maternal antibodies or antibody serum injection. Active immunity may be acquired through natural exposure to a pathogen or through vaccination.	Note: The focus could be on acquired immunity in humans; however, other animals could be considered. Compare acquiring immunity via passive and active mechanisms. Examples include: antibodies in breastmilk, vaccinations and importance of booster vaccinations. Use graphs to analyse how the immune system responds to pathogens after vaccination using the memory cells of the adaptive immune system. Debate the ethics of vaccination, including examples of where vaccination programs have eradicated disease in a population (e.g. smallpox, measles, polio). Outline the reasons such as decrease in vaccination rate and antigen variation, for the re-emergence of disease such as measles. Investigate the accessibility of life-saving medications, such as: vaccinations (e.g. influenza, chicken pox) and medications (e.g. anti-malaria) that can be used to combat pathogens.

Science Understanding	Possible Strategies, Contexts, and Activities
	Examine the role of biotechnology in the developments of vaccinations to combat disease outbreaks, e.g. annual influenza ‘flu’ shot.

Topic 3: Multicellular Organisms

In this topic, students examine the structure and function of various multicellular organisms, which could include the investigation of human, insect, and/or plant systems.

Students examine the hierarchical structure of organisms and look at the arrangement and characteristics of cells, tissues, organs, and organ systems. They explore the concepts of cell differentiation and gene expression.

Students consider the structure and function of various organ systems in human beings and other species, including specific attributes of the circulatory, respiratory, excretory, and digestive systems in animals.

Plants are also important multicellular organisms that provide a source of food for many animal species. In their study of this topic, students investigate the factors that affect plant growth and to learn about the structure and function of leaves and their role in photosynthesis. Xylem and phloem are important tissues in plants that are responsible for water and nutrient transport throughout the plant.

Students develop an understanding of how biotechnology has contributed to not only the understanding of how systems within multicellular organism function together but also how it has enabled new development of medical treatments based on genetic factors.

Science Understanding	Possible Strategies, Contexts, and Activities
Specific cell structure and functions develop through cell differentiation. • Recognise that: - cells in a multicellular organism are genetically identical - gene expression is responsible for cell specialisation.	Explore, using examples: – how genes can be switched on/off – repressor proteins – gene expression during embryo development. Discuss the role of environmental factors and/or epigenetics on the phenotype of individuals. Construct a model microarray of gene expression and analysis expression data. Useful websites include: www.ashg.org/education/gena/GeneExpression_L3_corrected.pdf (This site has instructions on how to construct and do an investigation on microarray to show differential gene expression.) Investigate gene therapies to prevent or correct the expression of genes that result in genetic diseases (e.g. cancer or cystic fibrosis).
Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs, and systems. • Use examples from plants and animals to explain organisation of cells into tissues, tissues into organs, organs into systems. • Illustrate the relationship between the structure and function of cells,	Examine the organisation of cells, tissues, organs, and systems in plants and animals. Compare other multicellular organism systems to the structure and function of human systems. Use virtual or actual organ dissections, e.g. virtual frog dissection or hands-on practical activity using goat/sheep heart or kidneys or flower dissection.

Science Understanding	Possible Strategies, Contexts, and Activities
tissues, organs, and/or systems. Organ systems in a multicellular organism are interdependent and function together to ensure the survival of the organism. Lifestyle choices affect the functioning of organs and systems.	View videos to show the functions of cells, tissue, and organs. Look at specimens of cells from different tissues and organisms from various organisms using the microscope. Useful websites include: www.mhhe.com/biosci/genbio/virtual_labs/BL_16/BL_16.html (This shows simulation of a virtual frog dissection). www.biologycorner.com/worksheets/frog_alternative.html (This site has useful worksheets for the virtual simulation of the frog dissection.) www.youtube.com/watch?v=AAe3cabBLaM&feature=youtu.be (This site shows heart cells beating.) Investigate the ethics of using animals in scientific experiments. Research the effect of lifestyle choices on the function of organs and systems, e.g. effect of smoking on the structure and function of the lungs. Investigate the consequence of uncontrolled cell division that may results from lifestyle factors, such as exposure to carcinogens (e.g. lung cancer and its link with smoking).
Multicellular organisms exchange materials with their environment. Exchange surfaces in an organism must be thin, moist, and have a large surface area. In animals, the exchange of gases by diffusion between the internal and external environments of the organism is facilitated by the structure and function of the respiratory system. • Describe the process of diffusion as a passive process that does not require additional input of energy.	Give examples of materials taken in and released by multicellular organisms. Discuss the features of exchange surfaces that enable them to function efficiently: – thin – moist – large surface area – blood supply in close vicinity. Relate the structure of, for example, alveoli and/or gills to their function. Recognise that the respiratory and circulatory systems are interconnected and function together. Investigate lung capacity before and after physical activity. Investigate the effect of various factors on lung function (e.g. ambient temperature, gender or exercise). Use the Balloon Lung investigation to model the respiratory system. Consider tidal volume, residual volume, and vital capacity. Use organs from sheep (or similar) to: – show the connection of the circulatory

Science Understanding	Possible Strategies, Contexts, and Activities
	and respiratory systems – inflate the lungs – perform a lung dissection – examine the blood vessels connecting the heart to the lungs. Investigate lifestyle diseases related to the respiratory system (emphysema, lung cancer, pneumonia, asthma). Pose questions such as: – Is there a difference between the lung capacities of non-athletes and athletes? – What are the benefits of exercise for the individual?
In plants, gas exchange is facilitated by the structure of the leaf. Gases are exchanged mainly via stomata. Their movement within the plant is by diffusion and does not involve the plant transport system.	Examine the structure and function of the different cell types in a leaf. Look at stomata and chloroplasts using a microscope (e.g. nail varnish impressions), the density of stomatal density, examine the guard cells. Measure transpiration under different conditions. Research ways of reducing transplant shock in plants by blocking stomata.
In animals, the digestive system is responsible for the breakdown of food and absorption of nutrients required for survival. • Relate the structure of organs of the digestive system to their function. • Describe the structure and function of villi in the human digestive system.	Construct a table to summarise the major macromolecules (e.g. proteins), their monomers (e.g. amino acids), and their specific digestive enzymes (e.g. proteases) Describe how different nutrients are absorbed through the villi by various transport processes including diffusion, active transport, and endocytosis. Compare digestive systems from various animals (e.g. ruminants, insects, and birds). Investigate digestive enzymes and factors that may affect their function (e.g. amylase and pH or lipase and temperature). Perform experiments to show the products of digestion are the monomers of macromolecules, e.g. use of Benedict's solution and Sudan III.
In plants, the uptake of nutrients and water is facilitated by the structure of the root system.	Examine the structure of roots and root hairs in different plants.
In animals, the excretory system is responsible for the removal of wastes. • Describe the structure and function of nephrons in the kidney in the human excretory system.	Locate the major tissues and organs of the excretory system. Discuss the process of osmoregulation and its control by hormones e.g. anti-diuretic hormone.

Science Understanding	Possible Strategies, Contexts, and Activities
• Explain the importance of filtration and reabsorption.	Investigate the effect of caffeine and alcohol on osmoregulation. Investigate the way in which the composition of urine changes due to various factors, e.g. disease, injury. Dissect and examine a kidney from a sheep or goat. Construct a working model of a kidney/nephron. Investigate the process of filtration in the nephron using artificial blood. Investigate how dialysis as a replacement for the kidney has saved lives. Debate the use of live or deceased donors for organ transplants. Discuss the ethical considerations of live organ donations. Explore innovative technologies, such as 3D bio-printers to produce kidneys that are genetically matched to the recipient.
In plants waste material may be removed or stored.	Investigate salt removal in mangroves.
In animals, the transport and exchange of materials is facilitated by the structure and function of the circulatory system. The lymphatic system is closely connected to the circulatory system. • Compare the role of blood capillaries and lymph capillaries in the exchange of materials.	Locate the major tissues and organs of the circulatory and lymphatic systems. Examine the structural differences between arteries, veins and capillaries. Compare the circulatory systems of different animals, such as insects, fish, birds, frogs. Dissect a fish to investigate the circulatory system of a non-mammalian animal. Dissect a mammalian heart (e.g. pig, cow, sheep, or goat). Investigate the effect of exercise on heart rate. Research the functioning of: − an artificial heart − pacemaker − heart-lung machine. Explain how these devices have saved the lives of many waiting for a heart transplant. Discuss lifestyle choices in relation to how exercise, nutrition, and drug use can affect the circulatory system and cause many heart conditions, including heart disease, cardiomyopathy, and arteriosclerosis.

Science Understanding	Possible Strategies, Contexts, and Activities
In plants, transport of water and mineral nutrients from the roots occurs via xylem involving: – root pressure – transpiration – cohesion of water molecules – osmosis. Transport of the products of photosynthesis and some mineral nutrients occurs by translocation in the phloem. They may be stored for later use.	Examine the arrangement of xylem and phloem in the roots, stem and leaves of the plant (e.g. vascular bundles). Use white flowers (e.g. Carnations) in coloured water to illustrate water movement through plant tissue. Discuss the storage of, for example, starch in tubers. Describe adaptations of plants that facilitate water conservation, e.g. colour of leaves, shape of leaves, waxy cuticle, number of stomata. Compare the size and/or distribution of stomata in plants from different environmental conditions. Research the effects of climate change on the distribution of plants. Inquire into the impact of rainforest clearing and the effect on animals (e.g. palm oil production on orang-utan). Investigate the role and ethics of using biotechnology in the production of plant species that are genetically altered to suit different environmental conditions (e.g. temperature, water availability).

Topic 4: Biodiversity and Ecosystem Dynamics

The current view of the biosphere is of a dynamic system composed of Earth's diverse, interrelated, and interacting ecosystems. This concept has been developed from the work of eighteenth and nineteenth century naturalists, who collected, classified, measured, and mapped the distribution of organisms and environments around the world.

In this topic, students investigate diverse ecosystems, exploring the range of biotic and abiotic components to understand the dynamics, diversity, and underlying unity of these systems.

Students develop an understanding of the processes involved in the movement of energy and matter in ecosystems. They investigate ecosystem dynamics, including interactions within and between species, and interactions between abiotic and biotic components of ecosystems. They also investigate how measurements of abiotic factors, population numbers and species diversity, and descriptions of species interactions, can form the basis meaningful comparisons between ecosystems. Students use classification keys to identify organisms, describe the biodiversity in ecosystems, and investigate patterns in relationships between species.

When undertaking fieldwork, students individually and/or collaboratively collect first-hand data and experience interactions in local ecosystems. To understand the interconnectedness of organisms, the physical environment, and human activity, students analyse and interpret data collected through investigation of a local environment and from sources relating to other Australian, regional, and/or global environments.

Science Understanding	Possible Strategies, Contexts, and Activities

Biodiversity is the variety of all living things and includes diversity in genetics, species and ecosystems.
• Distinguish between a species, population, community, and an ecosystem.
• Describe diversity in examples of
  - species
  - ecosystems.
In general, the higher the biodiversity of an ecosystem the more stable it is.
	Examine biodiversity at the level of molecular (genetic), population, and ecosystem levels.
	Explore the variety of different species within an ecosystem and link with the concept of classification of organisms.
	Investigate the work of pioneers in taxonomic biology, including Carl Linnaeus and his work in binomial classification.
	Research the work of naturalists such as Charles Darwin and Joseph Banks.

Biological classification is hierarchical and indicates the relationship between organisms based on their physical structures and the similarities in shared molecular sequences. The internationally agreed nomenclature of species is based on a system devised by Linnaeus in the 18th Century. • Distinguish between scientific names and common names for species. • Recognise that very closely related species have similar scientific names. Different species show different features	Examine and compare morphological features of organisms that are more or less closely related. Use biological (dichotomous) keys to classify organisms. Research the limitations and refinements of the current nomenclature system. Visit a zoo, regional park, or botanic garden to compare features of groups of organisms. Compare distinctive morphological features of a group of plants from a specific community and relate their features to the role they play in

Science Understanding	Possible Strategies, Contexts, and Activities
that help maintain their reproductive isolation. Reproductive isolating mechanisms may be pre-zygotic or post zygotic.	sustaining the plant. Produce a herbarium of common native plants showing features that indicate their relationship. Investigate the Wellcome Trust 'Tree of Life' to view the inter-relationships of some species: www.wellcometreeoflife.org/ *Note the potential link forward with Stage 2 Topic 1: DNA and Proteins.*
Organisms have adaptations that help them survive and reproduce. • Discuss examples of adaptations in plants and animals.	Compare structural, behavioural, and physiological adaptations of different species from specific environments. Simulate bird beaks and different food types to see how adaptations influence survival.
Ecosystems can be diverse, and can be defined by their biotic and abiotic components and the interactions between elements of these components. • Distinguish between biotic and abiotic components of ecosystems. • Compare the characteristics of at least two ecosystems. Patterns within a community include zonation and stratification.	Investigate *in the field* a specific community – examine the relationship between the abiotic factors influencing the community and the organisms in the community. During the field investigation consider features such as: – food webs and food chains – inter- and intraspecific interactions such as symbiosis, competition, predation, and disease – develop skills relating to suitable sampling techniques such as transect and quadrat analysis. A range of resources is available from the Nuffield Foundation: www.nuffieldfoundation.org/practical-biology/topics Research the work of early ecology pioneers who inspired modern environmentalism such as: – A Tansley who coined term 'ecosystem'), – G E Hutchinson, who promoted idea of 'niche' – Rachel Carson, who wrote *Silent Spring.*
The biotic and abiotic components of ecosystems interact with each other to capture, transform, and transfer energy. Nutrients within an ecosystem are involved in biogeochemical cycles. • Represent the water cycle and	Examine energy loss and transformation between trophic levels. Explore how humans have affected the biogeochemical cycles due to activities such as the use of fertilisers. Research innovative methods of bio-

Science Understanding	Possible Strategies, Contexts, and Activities
biogeochemical cycles, for elements such as nitrogen, phosphorous, and carbon. Humans can interfere with natural cycles.	recycling of waste. Examine the implications for the future of species, including the human population.
Ecosystems include populations of organisms that each fills a specific ecological niche. • Describe a niche in terms of key indicators within the ecosystem, including habitat, feeding relationships, and interactions with other species. Keystone species play a critical role in the maintenance of their ecosystem. • Explain the significance of keystone species in their ecosystem.	Relate the concept of a keystone species to the large impact that would be experienced by an ecosystem if numbers of the keystone species were to decline substantially. Graphically represent the niche of different organisms to discover the extent of niche overlap. Research local examples of keystone species such as grey nurse shark (*Carcharias taurus*), and the red-tailed cockatoo (*Calyptorhynchus banskii*). www.australiangeographic.com.au/topics/wildlife/2014/09/australias-keystone-endangered-species Investigate how critically endangered species are being conserved.
Ecosystems can change over time. Ecological succession involves changes in biotic and abiotic components and their dynamic influence on each other. • Describe examples of succession. Evidence for longer term changes can be found in geological deposits including the fossil record.	Compare examples of primary and secondary succession. Use fossil evidence to suggest how the environment has changed over very long periods of time. Follow the natural progression of mould on bread or fruit over several weeks, or the colonisation of an agar plate. *(Note: care must be taken if working with microorganisms that may include pathogens)* Visit a local museum of natural history or fossil bed and compare fossils from one site to examine evidence of how the environment has changed over time. Research the discovery of Ediacaran fossils in Flinders Ranges. Inquire into the history and value of such sites as Naracoorte Caves and Dinosaur Stampede National Monument, Winton (Qld).
Humans have significant impacts on ecosystems. • Explain why how the destruction of habitats as a result of human activity speeds changes in	Use trends in changes of key components of the biotic and abiotic components of the ecosystem to predict the likely future changes in an ecosystem.

Science Understanding	Possible Strategies, Contexts, and Activities
ecosystems and impacts on biodiversity. By measuring key aspects of the biotic and abiotic components of the ecosystem, it is possible to make predictions relating to the impact of environmental change. • Describe how these predictions can help to develop strategies to minimise the adverse effects of such change.	Examples may include: – atmospheric CO_2 levels – sea temperature – population size of key (or keystone) species. Graphically represent trends in key environmental variables including: – atmospheric CO_2 – air and sea temperature – pH of the sea – polar ice cover and extrapolate trends over the coming decades. Investigate how human activities such as deforestation, the use of fertilisers, and chemical poisons in monoculture agricultural systems affect the speed of change in natural ecosystems. Research an affected ecosystem such as a tropical rainforest that has been completely cleared to be replaced by cash crops. Research the plight of the orang-utan or other large animal that has become endangered due to habitat destruction.
Populations with reduced genetic diversity face increased risk of extinction. • Explain why genetic diversity is important for a species' survival in a changing environment.	Discuss 'genetic bottlenecks'. Research specific endangered species that have limited genetic diversity and discuss the implications for the species. Examples of species with limited genetic diversity include cheetahs (Africa), Gilbert's potoroo (SW Australia), and the black robin (NZ). Investigate the preservation of species using breeding programs at a local zoo, animal park, or plant nursery. Examine human activities that have contributed to the lack of genetic diversity in some species. Research some of the steps being taken to improve the chances of survival of endangered species.

ASSESSMENT SCOPE AND REQUIREMENTS

At Stage 1, assessment is school-based.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 1 Biology.

- Assessment Type 1: Investigations Folio
- Assessment Type 2: Skills and Applications Tasks

For a 10-credit subject, students provide evidence of their learning through four assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least one practical investigation
- at least one science as a human endeavour investigation
- at least one skills and applications task.

For a 20-credit subject, students provide evidence of their learning through eight assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least two practical investigations
- at least two science as a human endeavour investigations
- at least two skills and applications tasks.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by teachers to:

- clarify for the student what he or she needs to learn
- design opportunities for the student to provide evidence of his or her learning at the highest level of achievement.

The assessment design criteria are the specific features that:

- students should demonstrate in their learning
- teachers look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described below.

The set of assessments, as a whole give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Design of a biological investigation

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats

IAE3 Analysis of data and other evidence to formulate and justify conclusions

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of biological concepts

KA2 Application of biological concepts in new and familiar contexts

KA3 Demonstration of understanding of science as a human endeavour

KA4 Communication of knowledge and understanding of biological concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio

For a 10-credit subject, students undertake at least one practical investigation and one investigation with a focus on science as a human endeavour.

For a 20-credit subject, students undertake at least two practical investigations and two investigations with a focus on science as a human endeavour.

Students inquire into aspects of biology through practical discovery and data analysis, or by selecting, analysing, and interpreting information.

Practical Investigations

As students design and safely carry out investigations, they develop and extend their science inquiry skills by formulating investigable questions and hypotheses, selecting and using appropriate equipment, apparatus, and techniques, identifying variables, collecting, representing, analysing, and interpreting data, evaluating procedures and considering their impact on results, drawing conclusions, and communicating their knowledge and understanding of concepts.

Practical investigations may be conducted individually or collaboratively, but each student should present an individual report. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical report should include:

- introduction with relevant biological concepts, a hypothesis and variables, or investigable question
- materials/apparatus, method/procedure outlining steps to be taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of procedures and data, and identifying sources of uncertainty
- conclusion.

The report should be a maximum of 1000 words if written, or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form.

*The materials/apparatus, method/procedure outlining steps to be taken, identification and management of safety and/or ethical risks, and results sections are excluded from the word count.

Suggested formats for presentation of a practical investigation report include:

- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of biology with an emphasis on science as a human endeavour. This investigation focuses on at least one aspect of science as a human endeavour described on pages 13 and 14 and may draw on a context suggested in the topics being studied or explore a new context.

Student consider, for example:

- how humans seek to improve their understanding and explanation of the natural world
- how working scientifically is a way of obtaining knowledge that allows for the analysis of scientific claims, but also allows for change in scientific theory in the light of new evidence. These changes may be due to technological advances
- the role of social, ethical, and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically, and hence speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact and influence on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

Possible starting points for the investigation could include, for example:

- an article from a scientific journal (e.g. Cosmos)
- critiquing a blog or TED talk based on a biological impact
- an advertisement or a film clip in which a biological concept is misconstrued
- an expert's point of view
- a new development in the field of biological science endeavour
- the impact of a technique and its historical development
- concern about an issue that has environmental, social, economic, or political implications
- emerging biology-related careers and pathways.

- changes in government funding for biology-related purposes, e.g. for scientific research into biotechnology, conservation planning, hormone use in food production, safe disposal of nuclear waste, bio-security, water quality, greenhouse effect, energy supplies, disease control, health.

The science as a human endeavour investigation should be a maximum of 1000 words if written or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks

For a 10-credit subject, students undertake at least one skills and applications task.

Students may undertake more than one skills and applications task, but at least one should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

For a 20-credit subject, students undertake at least two skills and applications tasks. Students may undertake more than two skills and applications task, but at least two should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

Skills and applications tasks allow students to provide evidence of their learning in tasks that may be:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

A skills and applications task may require students to, for example: use biological terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically or graphically; design an investigation to test a hypothesis or investigable question.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key biological concepts and learning, and the science inquiry skills covered in the program. Students use appropriate biological terms and conventions to explain links between biological concepts, and apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context.

Skills and applications tasks may include:

- modelling or representing concepts
- developing simulations
- a practical assessment such as a ‘completion practical’ with associated questions
- a graphical skills exercise
- a multimodal product
- an oral presentation
- a video or audio recording
- participation in a debate
- an extended response
- a written assignment
- a structured interview

- an excursion report
- a historical study
- multiple-choice questions
- short-answer questions
- a response to text(s).

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:
- investigation, analysis, and evaluation
- knowledge and application.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills and understanding that teachers refer to in deciding how well a student has demonstrated his or her learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of a subject, the teacher makes a decision about the quality of the student's learning by:
- referring to the performance standards
- taking into account the weighting of each assessment type
- assigning a subject grade between A and E.

Performance Standards for Stage 1 Biology

	Investigation, Analysis and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed biological investigation. Obtains records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effects on data.	Demonstrates deep and broad knowledge and understanding of a range of biological concepts. Applies biological concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of biology coherently with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear biological investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of biological concepts. Applies biological concepts mostly effectively in new and familiar contexts. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of biology mostly coherently with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear biological investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of biological concepts. Applies biological concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of biology generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a biological investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of biological concepts. Applies some biological concepts in familiar contexts. Identifies some aspect of science as a human endeavour. Communicates basic biological information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a biological investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of biological concepts. Attempts to apply biological concepts in familiar contexts. Shows some recognition of science as a human endeavour. Attempts to communicate information about biology.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (wwww.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement in the school assessment are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 1 are available on the SACE website (www.sace.sa.edu.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.gov.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website. (www.sace.sa.edu.au).

Stage 2 Biology

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 2 Biology.

In this subject, students are expected to:

1. use science inquiry skills to design and conduct biological investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, and analyse the results of biological investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. demonstrate and apply knowledge and understanding of biological concepts in new and familiar contexts
5. demonstrate understanding of science as a human endeavour
6. communicate knowledge and understanding of biological concepts and information, using appropriate terms, conventions and representations.

CONTENT

Stage 2 Biology is a 20-credit subject.

Stage 2 Biology focuses on the development of an understanding of the overarching principles of biology, such as the relationship between structure and function, the importance of regulation and control, and the need for the exchange of materials and the transformation of energy. These principles, together with that of the continuity of life, involving adaptation and change, provide a framework within which students can explore aspects of biology from the microscopic to the macroscopic, and make sense of the living world.

Science inquiry skills and science as a human endeavour are integral to students' learning in this subject and are interwoven through the science understandings, which are organised into four topics. The science inquiry skills and the understanding of science as a human endeavor, which can be developed through practical and other learning activities in each topic, are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections pages that follow.

Programming advice

Stage 2 Biology consists of the following topics:

- Topic 1: DNA and Proteins
- Topic 2: Cells as the Basis of Life
- Topic 3: Homeostasis
- Topic 4: Evolution

Students study all four topics, with the *Science Inquiry Skills* and *Science as a Human Endeavour* sections integrated into the science understanding.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the prescribed content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

indicates a possible teaching strategy

indicates a possible activity to develop Science Inquiry Skills

indicates a possible Science as a Human Endeavour context

An inquiry-based approach is integral to the development of science understanding. The *Possible Strategies, Contexts, and Activities* column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop and extend their knowledge, skills, and understanding.

Science Inquiry Skills

In Biology investigation is an integral part of the learning and understanding of concepts, by using scientific methods to test ideas and develop new knowledge.

Practical investigations involve a range of individual and collaborative activities during which students develop and extend the skills the science inquiry skills described in the table that follows.

Practical activities may take a range of forms, such as developing models and simulations that enable students to develop a better understanding of particular concepts. They include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students display and analyse the data they have collected, evaluate procedures and describe their limitations, consider explanations for their observations, and present and justify conclusions appropriate to the initial question or hypothesis.

It is recommended that 16–20 hours of class time would involve practical activities.

Science inquiry skills are also fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically consider the evidence they obtain so that they can present and justify conclusions.

Science inquiry skills are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes the prescribed teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop and extend student understanding of science inquiry skills. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – hypothesis or inquiry question – types of variables ➢ dependent ➢ independent ➢ factors held constant (how and why they are controlled) ➢ factors that may not be able to be controlled (and why not) – materials required – the procedure to be followed – the type and amount of data to be	Class activities to develop skills could include: – designing investigations without implementation – changing an independent variable in a given procedure and adapting the method – researching developing, and trialling a method – improving an existing procedure – identifying options for measuring the dependent variable – researching hazards related to

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
collected – identification of ethical and safety considerations	the use and disposal of chemicals and/or biological materials – developing safety audits – identifying relevant ethical and/or legal considerations in different contexts.
Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. • Conduct investigations, including: – selection and safe use of appropriate materials, apparatus, and equipment – collection of appropriate primary and/or secondary data (numerical, visual, descriptive) – individual and collaborative work.	Class activities to develop skills could include: – identifying equipment, materials, or instruments fit for purpose – practising techniques and safe use of apparatus – comparing resolution of different measuring tools – distinguishing between and using primary and secondary data.
Results of investigations are presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including – use of appropriate SI units, symbols – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	Class activities to develop skills could include: – practising constructing tables to tabulate data, including column and row labels with units – identifying the appropriate representations to graph different data sets – selecting appropriate axes and scales to graph data – clarifying understanding of significant figures using, for example: www.astro.yale.edu/astro120/SigFig.pdf www.hccfl.edu/media/43516/sigfigs.pdf www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm – comparing data from different sources to describe as quantitative, qualitative.
Scientific information can be presented using different types of symbols and representations. • Select, use, and interpret appropriate representations, including: – mathematical relationships, such as ratios – diagrams – equations to explain concepts, solve problems, and make predictions.	Class activities to develop skills could include: – writing chemical equations – drawing and labelling diagrams – recording images – constructing flow diagrams.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
Analysis of the results of investigations allows them to be interpreted in a meaningful way. • Analyse data, including: – identification and discussion of trends, patterns and relationships – interpolation/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent variables – using graphs from different sources, e.g. CSIRO or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity – reliability – effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions.	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. www.biologyjunction.com/sample%20ap%20lab%20reports.htm
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and bibliographies – opportunities to practice scientific communication in written, oral, and multimedia formats, e.g. presenting a podcast or writing a blog.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through their exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

3. Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural and ethical considerations.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, and environmental impacts, offer valid explanations, and make reliable predictions.

- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.

- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline and the understandings should be integrated and used in a 20-credit program, as points of reference for student learning.

The symbols in the right-hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Topic 1: DNA and Proteins

Heredity is an important biological principle as it explains why new cells or offspring resemble their parent cell or organism. Some organisms require cellular division and differentiation for growth, development, repair, and sexual reproduction. Students investigate the structure of DNA and its discovery, and processes involved in the transmission of genetic material to the next generation of cells and to offspring. They also develop an understanding of how genetic information is expressed in cells and organisms, and how interactions between genes and environmental conditions influence an organism’s characteristics.

Students relate gene expression to protein production and explore the some of the array of roles that proteins have in a functioning cell and organism.

Science Understanding	Possible Strategies, Contexts, and Activities
DNA stores and transmits genetic information; it functions in the same way in all living things. DNA is a helical double-stranded molecule bound to proteins in chromosomes in the nucleus of eukaryotes, as unbound circular DNA in the cytosol of prokaryotes, and in the mitochondria and chloroplasts of eukaryotic cells. Replication of DNA allows for genetic information to be inherited. The structural properties of the DNA molecule, including nucleotide composition and pairing, and the weak bonds between strands of DNA, allow for replication. Base-pairing rules and method of DNA replication are universal. • Explain the importance of complementary base pairing (A-T and C-G). • Describe and represent the process of semi-conservative replication of DNA.	Review prokaryotic and eukaryotic cells. Construct and use models of DNA replication, to communicate conceptual understanding, solve problems and make predictions. Extract DNA (e.g. from peas). Explore the work of Watson, Crick, Franklin, and Wilkins in the discovery of the structure of DNA. Illustrate the mechanism of semi-conservative replication through models showing complementary base-pairing. www.phet.colorado.edu/en/simulation/stretching-dna
A gene consists of a unique sequence of nucleotides that code for a functional protein or an RNA molecule. • Distinguish between exons and introns as coding and non-coding segments of DNA found in genes. • Describe how both exons and introns are transcribed but only the information contained in exons will be translated to form a polypeptide.	Note that prokaryotic cells do not have introns. Discuss the end products of genes including functional proteins, tRNA, rRNA and microRNA.
Protein synthesis involves transcription of a gene into messenger RNA (mRNA), and translation of mRNA into an amino acid	Construct and use appropriate representations, including models of transcription and translation, to

Science Understanding	Possible Strategies, Contexts, and Activities
sequence at the ribosomes. In eukaryotic cells, transcription occurs in the nucleus. • Describe and illustrate the role of DNA, mRNA, transfer RNA (tRNA), ribosomal RNA (rRNA) in transcription and translation. • Describe the relationship between codons, anticodons, and amino acids.	communicate conceptual understanding of the roles of mRNA, tRNA, and ribosomes.
The folding of a polypeptide to form a protein with a unique three-dimensional shape is determined by its sequence of amino acids. • Describe the factors that determine the primary, secondary, tertiary, and quaternary structure of proteins.	Illustrate, using examples, how the primary and secondary structure of a protein determines its tertiary (three-dimensional) structure. Discuss examples of proteins that combine into a quaternary structure (e.g. haemoglobin, DNA polymerase). Investigate the design and manufacture of proteins for scientific/medicinal use. Examples include biochips, biomaterials, diagnostics, and targeted chemotherapy.
Proteins, including enzymes, are essential to cell structure and functioning. Examples of other proteins with specific shapes include some hormones, receptor proteins, and antibodies. • Explain why the three-dimensional structure of a protein is critical to its function. Enzymes: - are specific for their substrate - increase reaction rates by lowering activation energy. • Describe the induced-fit model of enzyme–substrate binding. • Explain why enzymes have specific functions and how they can be affected by factors including: – temperature – pH – presence of inhibitors – concentrations of reactants – concentration of products.	Discuss examples of proteins whose three-dimensional structure can facilitate the recognition and binding of specific molecules, including enzymes and substrates, and cell membrane receptors and hormones. Use examples to emphasise enzyme specificity and reinforce the importance of the three-dimensional shape of proteins. Investigate the effect that conditions such as temperature, pH, substrate concentration, product concentration, chemical inhibitors can have on enzyme activity. Research the use of enzyme inhibitors in: - pesticides (e.g. glyphosate) - drugs (e.g. ritonavir) - chemotherapy.
The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment. DNA methylation can affect gene expression. • Explain the effect of DNA	Discuss DNA methylation. Explore the work and influence of Prof. Stephen Baylin. Explore some example of diseases caused by epigenetics such as Fragile X syndrome and Rett syndrome.

Science Understanding	Possible Strategies, Contexts, and Activities
methylation. Epigenetic changes can cause human diseases. Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth.	Revise the concept of cell differentiation.
Changes in the DNA sequence are called ‘mutations’. Mutations in genes and chromosomes can result from errors in DNA replication or cell division, or from damage by physical or chemical factors in the environment. Mutation rate can be increased by: - ionising radiation - mutagenic chemicals - high temperature - viruses. • Explain how inheritable mutations can lead to changes in the characteristics of the descendants. • Describe the different potential consequences of mutations in germ cells and somatic cells.	Examine the cell cycle (including checkpoints). Describe the effect of mutations such as point, frameshift, or involving parts of or whole chromosomes on the genetic code and overall protein formation. Discuss examples of the impacts of mutations (genetic diseases). Debate social and ethical issues relating to gene therapy.
DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals. Human beings can sequence even small amounts of DNA. Segments of DNA can be multiplied using the polymerase chain reaction (PCR); their base sequences can then be identified. • Describe PCR, including the roles of – heating and cooling – primers – free nucleotides – heat-resistant enzymes – electropherograms. • Explain how differences in DNA fragments, identified by DNA profiling, can be used, for example, in forensic science.	Discuss the use of PCR, short tandem repeats, and fluorescent labelling for DNA profiling Research the historical importance and contemporary applications of the work of: - Sir Alec Jeffreys and his use of RFLPs and VNTRs - Dr Kary Mullis inventing PCR in 1983. Investigate Low Template DNA Analysis.
Biotechnology can involve the use of bacterial enzymes, plasmids as vectors, and techniques including gel electrophoresis, bacterial transformations and PCR DNA can be extracted from cells. • Describe how particular genes can be selected and removed using probes and restriction enzymes,	Study examples of transgenic organisms and their uses, for example in food production and the production of human hormones. Investigate historical perspectives on selective breeding and more recently, cloning.

Science Understanding	Possible Strategies, Contexts, and Activities
including the latest technology such as CRISPR and CAS9. • Describe how selected genes can be transferred between species; for example, using bacterial plasmids, viruses, and microinjection.	Debate the social and ethical advantages and consequences of the manipulation of DNA. Explore bioethical issues of using CRISPR raised by Jennifer Doudna.

Topic 2: Cells as the Basis of Life

The cell is the basic unit of life. All cells possess some common features: all prokaryotic and eukaryotic cells need to exchange materials with their immediate external environment in order to maintain the chemical processes vital for cell functioning. In this topic, students examine the cell theory, the structure and function of the cell membrane, the exchange of materials, and processes required for cell survival. Students investigate the importance of enzymes in cell metabolism and ways in which energy is transformed and transferred in the biochemical processes of photosynthesis and respiration.

Students investigate events that occur during binary fission and mitotic cell division, and how they determine the degree of similarity between parent cells and daughter cells. They also consider the importance of culturing cells, and chemicals that interfere with cell metabolism.

Students explain how the evolution of cells from simpler to more complex structures and functions may have occurred.

Science Understanding	Possible Strategies, Contexts, and Activities
The cell theory unifies all living things. The cell membrane separates the cell from its surroundings and controls the exchange of materials, including gases, nutrients and wastes, between the cell and its environment. • Describe and represent the fluid mosaic model of the cell membrane.	Illustrate the structure of the cell membrane. Observe cells using microscope.
The major types of cell are - prokaryotic - eukaryotic. Prokaryotic and eukaryotic cells have many features in common, which is a reflection of their common evolutionary past. • Compare prokaryotic and eukaryotic cells with respect to their: – size – internal organisation – shape and location of chromosomes. Prokaryotes only exist as single cells.	Research the evidence of origin of life, e.g. stromatolites in Western Australia. Use animations or video clips to highlight the differences between prokaryotes and eukaryotes. www.ck12.org/biology/Prokaryotic-and-Eukaryotic-Cells/lesson/Prokaryotic-and-Eukaryotic-Cells/
Eukaryotic cells have specialised organelles which facilitate biochemical processes. • Represent the structure and describe the function of: – nucleus – nucleolus – mitochondrion – chloroplast – vacuole/vesicle – Golgi body – endoplasmic reticulum – ribosome – lysosome – cytoskeleton. • Compare the structure of plant and	Use electron photomicrographs to recognise organelles such as Golgi body, endoplasmic reticulum, mitochondria, chloroplasts, ribosomes.

Science Understanding	Possible Strategies, Contexts, and Activities
animal cells.	
Cells require inputs of suitable forms of energy, including light energy or chemical energy in complex molecules. • Distinguish between autotrophs and heterotrophs. Energy transformations occur within cells. The sun is the main source of energy for life. ▪ Recognise that photosynthesis is important in the conversion of light energy into chemical energy, as illustrated by the following equation: $6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$ $\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light}} \text{glucose} + \text{oxygen}$ • Recognise that energy is required to break chemical bonds and energy is released when new bonds are formed. • Explain how the ATP/ADP conversion provides energy for use in cells. • Explain how most autotrophs and heterotrophs transform chemical energy for use through aerobic respiration, as illustrated by the following equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ $\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$ • Explain that fermentation is an anaerobic alternative to aerobic respiration: in plants and yeast: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ $\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$ in animals: $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ $\text{glucose} \rightarrow \text{lactic acid}$ • Compare the amount of energy released through aerobic respiration and anaerobic respiration (fermentation).	Discuss the importance of light and chemical energy (photosynthesis and respiration). Investigate limiting factors that affect photosynthesis (e.g. using leaf discs). Explore the impacts of factors that affect photosynthesis impact on, for example, plants growing in different habitats or crop production. Investigate factors affecting anerobic respiration using yeast in solution or in a 'bread dough' mix.
Cells require an input of matter, including gases, simple nutrients, ions, and removal of wastes, to survive. • Compare the inputs and outputs of autotrophs and heterotrophs.	*Link this with Stage 1 Topic 1: Cells and Microorganisms.*

Science Understanding	Possible Strategies, Contexts, and Activities
Substances move in and out of cells by processes such as: - diffusion - facilitated diffusion - osmosis - active transport - endocytosis - exocytosis. • Explain how the structure of a membrane facilitates different processes of movement through it. • Explain how factors affect the exchange of materials across membranes including: – surface-area-to-volume ratio of the cell – concentration gradients – the physical and chemical nature of the materials being exchanged.	Review the role of the cell membrane. (*Stage 1 Topic 1: Cells and Microorganisms*) Explore the historical development of the fluid-mosaic model of membrane structure. Explain why composition of and conditions within the cell are important and need to be maintained. Use effects of osmosis to illustrate the need to regulate cellular composition. Use agar cubes, or cellulose tubing, starch and iodine solutions to investigate diffusion. Investigate factors affecting the rate of osmosis – for example in rhubarb epidermal cells.
Cell metabolism is critical to the survival of cells. Biochemical processes in the cell are controlled by: - the nature and arrangement of internal membranes - the presence of specific enzymes - environmental factors. • Explain how the structure of internal membranes of mitochondria and chloroplasts facilitate some biochemical processes. • Explain why metabolic pathways involve many small, regulated steps. • Explain that each step in a metabolic pathway produces intermediate compounds and loses some energy as heat. • Describe how a metabolic pathway is controlled by a specific enzyme at each step.	Use examples, such as glycolysis, Krebs cycle, photosynthesis to introduce metabolic pathways, including an explanation of the need for regulation. Review the effect of conditions such as temperature, pH, substrate concentration, product concentration, chemical inhibitors on enzyme activity. (*Stage 1 Topic 1: Cells and Microorganisms*) Use examples to emphasise enzyme specificity and reinforce the importance of the three-dimensional shape of proteins.
Chemicals can interfere with cell metabolism. • Discuss possible benefits and/or harmful effects of chemicals that human beings use.	Discuss the effects of chemicals such as cyanide, antibiotics, herbicides, and insecticides on cell metabolism.
Cells arise from pre-existing cells, and cell division leads to an increase in cell number.	Review the semi-conservative replication of DNA.

Science Understanding	Possible Strategies, Contexts, and Activities
Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis, and fertilization. • Explain why the amount of DNA in a cell doubles before division.	Revise the differences between prokaryotic and eukaryotic cells.
The products of mitotic division or binary fission have the same number and type of chromosomes as the parent. • Describe how prokaryotic cells divide by binary fission. • Recognise, describe, and illustrate the process of mitosis in eukaryotic cells. • Compare the products of mitotic division or binary fission with the number and type of chromosomes of the parent.	View animations to show the process of binary fission. Examine the stages of mitosis in onion root tip cells. Use models to represent the arrangement and movement of chromosomes during mitosis**.**
Diploid cells contain pairs of homologous chromosomes. • Recognise, describe and illustrate the process of meiosis in eukaryotic cells. • Explain why the products of meiosis are haploid cells, which contain a single set of chromosomes. • Explain the importance of crossing over and independent assortment in meiosis. • Explain that fertilisation restores the diploid number. • Compare the products of meiotic and mitotic cell division. • Describe the difference in sources and degree of genetic variation between the products of asexual and sexual reproduction. • Describe the difference between somatic cells and germ-line cells.	Use models to represent the arrangement and movement of chromosomes during meiosis. Construct and use diagrams to show the difference between haploid and diploid cells. Demonstrate how the processes of crossing over, independent assortment, and fertilisation contribute to genetic variation. Compare the sources of variation in sexual and asexual reproduction. Discuss the impact and ethics of genetic manipulation of somatic and germline cells.
Cell division may be regulated by internal and external factors. The cell produces gene products that regulate the cell cycle. • Explain that hormones may regulate cell division. • Carcinogens upset the normal	Review the link between genes and their products. Provide examples of hormones that regulate cell division, such as human growth hormone, or auxins and cytokinins in plants.

Science Understanding	Possible Strategies, Contexts, and Activities
controls of cell division by causing mutations.	Investigate examples of carcinogens: components of tobacco smoke, some dioxins, asbestos. 
Human beings culture cells for a variety of purposes. • Describe techniques of cell culture, and discuss the significance of contemporary examples of their use.	Review the requirements (nutritional and environmental) of cells and their need to eliminate waste products in the context of cell culture.  Examine examples of cell and tissue culture: HeLa cells, human skin replacement, vaccine production, plant tissue culture, the importance of yeast cultures. 

Topic 3: Homeostasis

In this topic, students examine some of the body systems, including the nervous, endocrine (hormonal), and excretory systems that play interdependent roles in the regulation of body processes such as body temperature, blood glucose levels, carbon dioxide levels in blood, and water balance. Students relate the structure of the cells, tissues, and organs of these systems to their function.

Students learn that homeostasis is the whole set of responses that occur in multicellular organisms, which enable their survival in their environment. Students develop an understanding that the cells in an organism work efficiently within tolerance limits that determine the optimal conditions for growth and survival.

Students develop an understanding that homeostasis is maintained through the stimulus response model and may involve negative feedback responses. To respond to changes in their internal and external environments, organisms must detect these stimuli through sensory receptors and then send messages to enable effectors to deliver the appropriate response to the stimulus.

By comparing the nervous and endocrine (hormonal) systems and examining their modes of action students understand how these systems operate together to maintain homeostasis for a number of regulated processes.

Students consider homeostasis in a range of organisms in animals and plants. They investigate processes in humans and other animals and consider the role of hormones in plant growth.

Students examine how biotechnology has contributed to advances in the treatment of malfunctioning of the nervous and endocrine systems.

Science Understanding	Possible Strategies, Contexts, and Activities
Homeostasis is the set of detections and responses that result in the internal environment of an organism remaining relatively constant. This increases the chances of survival. By maintaining a constant internal environment, organisms have an increased chance of survival. Organisms operate most efficiently within their tolerance limits. These tolerance limits include: - body temperature - water - blood glucose - carbon dioxide. • Discuss the impacts on an organism when conditions fall outside their tolerance limits.	Discuss Leibig: Law of Minimums, the impact of limiting factors in biological systems. Model the effects of tolerance limits by investigating the effect of salinity, pH, temperature, or other factors on seedlings. Examine the tolerance limits of organisms that exist in extreme environmental conditions, for example, hot springs, arctic locations. Science Nation: Extreme Microbes (US-NSF Video)
Organisms detect and respond to changes in the internal and external environment. In humans, this depends on the functioning of the nervous and endocrine system. The nervous system is composed of the	Discuss the importance of sensory receptors that detect changes in the internal and external environment, e.g. olfactory receptors, proprioceptors, taste receptors, receptors in the skin, pain receptor.

Science Understanding	Possible Strategies, Contexts, and Activities
central nervous system and the peripheral nervous system. • Describe the structure of a neuron. • Describe the function of sensory, inter- and motor neurons. • Describe the role of sensory receptors. • Describe the structure of a nerve pathway from receptor to effector. • Describe the role of synapses and neurotransmitters.	Discuss different neurotransmitters (e.g. norepinephrine, acetylcholine, cholinesterase, dopamine, serotonin). Analyse experimental evidence of the influence of anaesthetics, drugs, and chemicals, both natural and synthetic, on the functioning of the nervous system. Discuss the biological basis of neurological diseases such as Alzheimer's or Parkinson's disease, and how this relates to its treatment. Pose questions, such as: 'Why are some people more tolerant to pain than others?'
The endocrine system releases hormones that include proteins or steroids. Hormones travel to target sites via the circulatory or lymph system.	Discuss examples of endocrine (glands and the hormones they release) e.g. - hypothalamus/pituitary complex - thyroid - parathyroid - adrenal glands - islet cells of the pancreas.
Plants also produce hormone-like chemicals that can affect plant growth.	Discuss plant hormones such as: - abscisic acid - auxins - cytokinins - ethylene - gibberellins. Investigate the effect of plant hormones on plant growth. Research the use of plant hormones to, for example, stimulate growth, act as herbicides, stimulate flowering, ripen fruit.
Hormones can alter the metabolism of target cells, tissues or organs. • Compare the action of insulin and glucagon in blood sugar regulation. • Describe the action of thyroxine and thyroid stimulating hormone in metabolism. • Describe the role of anti-diuretic hormone (ADH) in osmoregulation. Hormonal responses are stimulated by either the nervous system or other hormonal messages.	Investigate the effects of chemotherapy on the endocrine system and hence homeostasis**.** Debate the unintended consequences of using hormones in medicinal situations such as growth hormone, HRT, thyroid hormones. Investigate the physiological consequences of hormone imbalances. (e.g. diabetes, Graves' disease).
Homeostasis involves a stimulus response model. • Explain the stimulus-response model.	Use examples to describe homeostatic processes and explain how these processes help body systems respond to a change in environment.

Science Understanding	Possible Strategies, Contexts, and Activities
• Describe the role and pathway of reflex responses. Negative feedback enables the homeostatic control of the internal environment at a relatively constant level. • Recognise that in negative feedback the response inhibits the initial stimulus.	Use examples to illustrate the function of reflex arcs (e.g. the patellar reflex, the pupillary reflex or hand on hot plate).
The nervous system and endocrine systems function independently or together to maintain homeostasis. • Compare the action of the endocrine and nervous control systems. • Explain how the nervous and endocrine systems work independently or together to: – control body temperature – enable osmoregulation – maintain blood sugar levels – regulate of carbon dioxide levels in blood.	Illustrate the effect of ADH on the nephron. Investigate the effects of exercise, coffee, and chocolate on heart rate, breathing rate or temperature or volume of urine. Use a flow diagram to represent the components of the stimulus-response model based on, for example, the control of body temperature.
Changes in the nervous and/or endocrine systems can limit the possible range of responses to stimuli. • Describe the impact of changes to the functioning of the – nervous system – endocrine system. • Explain how advances in technology may have both positive and negative effects on the functioning of various body systems and hence on homeostasis.	Discuss the physiological changes which lead to diabetes or other hormonally related diseases. Explore nerve damage which may lead, for example, to paralysis and paraplegia and investigate innovative technologies for its treatment (e.g. cochlear implants, artificial eyes). Evaluate the positive and negative uses of hormone therapy by humans (e.g. growth hormone and ageing, anabolic steroids and enhanced sporting performance). Evaluate the use of biotechnology to solve problems associated with lack of a hormone (e.g. insulin production or diabetes).

Topic 4: Evolution

Students examine the biological evidence that forms the basis for the theory of evolution by natural selection. In this topic, students investigate the genetic basis for the theory of evolution by natural selection through constructing, using, and evaluating explanatory and predictive models for gene pool diversity of populations. They explore genetic variation in gene pools, selection pressures, and isolation effects in order to explain speciation and extinction events and make predictions about future changes to populations.

Through the investigation of appropriate contexts, students explore ways in which models and theories related to natural selection, evolution, and population genetics, and their associated technologies, have developed over time and under the influences of social, cultural, economic, and ethical considerations. They investigate ways in which science contributes to contemporary debate about local, regional, and global issues, including evaluation of risk and action for sustainability, and recognise the limitations of science to provide definitive answers in different contexts.

Students use science inquiry skills to design and conduct investigations into how different factors affect processes in gene pools; they construct and use models to analyse the data gathered; and they continue to develop their skills in constructing plausible predictions and valid and reliable conclusions.

Science Understanding	Possible Strategies, Contexts, and Activities
Evidence shows that life has existed on Earth for around 3.5 billion years, during which time it has diversified.	Define the characteristics of all known life forms and list the features that they share, including nucleic acids and a cell membrane.
Existing cells are the products of evolution. Membranes may have formed spontaneously and the first simple cells may have used RNA as genetic information. Ribozymes may have played a role in this development. • Describe the possible roles of RNA and ribozymes in the first simple cells. There is evidence that prokaryotic cells existed before eukaryotic cells. • Describe this evidence, including fossil evidence. • Explain how the ancestry of most existing eukaryotic cells probably involved endosymbiotic events.	Discuss the evidence to illustrate the existence of life on Earth for around 3.5 billion years, including microfossils and geochemical evidence. Review the structure and function of mitochondria and chloroplasts. Investigate sea slugs as a recent example of endosymbiosis. Research the work and influence of Nobel Prize winners Altman, Cech, and Jack Szostak.
Comparative genomics provides evidence for evolution and helps establish the likely evolutionary relationship between different species. • Describe techniques for obtaining evidence including: – Amino acid sequencing of common proteins (e.g. cytochromes)	Describe modern techniques used to compare the likely evolutionary relatedness of species. Extract DNA from common sources: e.g. fruit, vegetables, liver. Useful sources: www.nuffieldfoundation.org/practical-biology/dna www.nuffieldfoundation.org/practical-biology

Science Understanding	Possible Strategies, Contexts, and Activities
– DNA-DNA hybridization – DNA profiling. Phylogenetic tree diagrams represent evolutionary relationships. • Draw and analyse simple phylogenetic tree diagrams to illustrate evolutionary relationships.	[2] www.nuffieldfoundation.org/content/extracting-dna-living-things www.eurovolvox.org/Protocols/PDFs/DNAnecklace02_UK_eng.pdf Compare known sequences of DNA in different species. Use gel electrophoresis to isolate DNA segments. Use known sequences of DNA or known sequences of amino acids to suggest phylogenetic relationships. Develop a time-line for biological change e.g. Nuffield activity: www.nuffieldfoundation.org/practical-biology/mapping-change-over-time www.nuffieldfoundation.org/node/1634/ www.wellcometreeoflife.org/video/ Research the use of technology in the study of comparative genomics, such as: - DNA databases (forensic & medical) - commercial DNA testing and what it can offer - the human genome project - mitochondrial DNA comparisons - identification of human remains by mtDNA (e.g. King Richard III of England, or natural disaster victims).
Different criteria are used to define a species depending on the mode of reproduction. A sexually reproducing species can be defined by the ability of its members to actually or potentially interbreed to produce fertile offspring. Other criteria used to define species include: - morphological similarity - biochemical similarity - sharing a common gene pool. • Discuss reproductive isolating mechanisms that maintain distinct species including: – Pre-zygotic (preventing zygote formation): ➢ temporal isolation ➢ behavioural isolation	Discuss the limitations of different criteria used to define a species. Give examples of pre- and post-zygotic isolating mechanisms maintain distinct species. Examples include courtship rituals, breeding seasons, and hybrids (ligers, zebrokey).

Science Understanding	Possible Strategies, Contexts, and Activities
➢ mechanical isolation ➢ gamete isolation – Post-zygotic (prevention of fertile hybrids) ➢ hybrid unviability ➢ hybrid sterility.	
Mutation is a permanent change in the sequence of DNA nucleotides and is the ultimate source of genetic variation in a species. Mutations may or may not result in a detectable physiological or biochemical change. Mutations can be advantageous, neutral, disadvantageous, or lethal. • Identify causes of mutation, such as: – ionising radiation – mutagenic chemicals – high temperature – viruses. In sexually reproducing species, fertilisation, independent assortment, and crossing over of chromosomes may also be sources of variation.	*Link to Stage 2 Topic 1: DNA and Proteins.* Review the structure and function of DNA. Recognise that the selection pressure may determine whether the mutation may be lethal, disadvantageous (but not lethal), neutral, or beneficial to an organism. Explain why many mutations will not be detected or will have no effect. Investigate examples of mutagenic factors in the environment, such as: - nicotine, tar, benzene and other polycyclic hydrocarbons - some elements (As, Cd, Br) - some viruses - high temperatures - X-rays, γ-rays, cosmic rays; - shorter wavelengths of UV (UV B). Resource: Monstrous mutations: from www.biologyjunction.com/ activity for this : www.biologyjunction.com/Monstrous%20Mutations.doc www.yourgenome.org/activities/kras-cancer-mutation www.geneed.nlm.nih.gov/topic_subtopic.php?tid=142&sid=145 Investigate why sickle-cell anaemia may be advantageous in malaria-prone environments. Use case studies to illustrate the effect of mutagens, including tobacco smoke, asbestos, and radium.
A gene pool comprises of all of the genetic information in an interbreeding population. • Recognise that a large gene pool usually indicates genetic diversity and is found in populations that are more likely to survive selection pressures.	Illustrate how the environmental selection pressures will determine the success of a group, rather than the group 'adapting' to the conditions. Describe the concept of gene flow and genetic drift. Explain how genetic drift and natural

Science Understanding	Possible Strategies, Contexts, and Activities
Natural selection is a process in which organisms that are better adapted to their environment are more likely to survive and produce offspring. • Explain how natural selection results in a change in the frequency of alleles in a population leading to evolution. Micro-evolutionary changes are affected by other factors besides mutation, including: - genetic drift - gene flow. If micro-evolutionary changes accumulate, they may lead to macro-evolutionary changes including speciation.	selection may have influences on different populations. Model natural selection using coloured counters or beads. Investigate the 'predation' of spaghetti worms: www.eurovolvox.org/Protocols/PDFs/BirdWorms_UK_1.1.pdf Investigate the concept of gene flow and genetic drift to show how gene frequency can change rapidly in some cases. Discuss the industrial melanism in peppered moths (*Biston betularia*). Research Darwin and Wallace and the impact of their contribution to the understanding of evolution.
Speciation may result from an accumulation of genetic changes influenced by different selection pressures in geographically isolated populations. • Describe the process of speciation due to physical separation (allopatric speciation). Note that isolation does not *cause* speciation. • Compare allopatric and sympatric speciation.	Describe how different selection pressures on isolated populations of a species may lead to natural selection producing different species that are related by a common ancestor. Investigate Peter and Rosemary Grant and the influence of their study of rapid evolution on the Galapagos Islands in the late 20th century.
Similar selection pressures in different environments may lead to convergent evolution. • Give examples of convergent evolution.	Research the independent evolution of eyes, placental and marsupial mammals, dugongs and whales.
When new niches become available to a species, for example as a result of succession or following an environmental change, different selection pressures may lead to divergent evolution or adaptive radiation. • Give examples of adaptive radiation. • Describe the process of succession.	Investigate adaptive radiation in marsupials, Darwin's finches or plants such as Brassicas, or any of New Zealand's native species that have well-documented studies in divergent evolution and adaptive radiation. Compare primary and secondary succession.
Species or populations that have a reduced genetic diversity have a higher risk of extinction. • Give examples of species with low genetic diversity.	Discuss the significance of examples of populations with reduced genetic diversity including cheetahs and Tasmanian devils.

Science Understanding	Possible Strategies, Contexts, and Activities
Human activities can create new and significant selection pressures on a gene pool, leading to species extinction. • Give examples of human activities that have caused or may threaten the extinction of species.	Investigate local, national, or global human activities that have had (or are having) a significant effect on species, including activities such as habitat destruction and the introduction of non-native species. Examine a specific case study, such as the dredging at Abbot Point, Queensland, and discuss the environmental impact reports. Debate the points of view for the logging of native forests in different states of Australia. Investigate how the influences of humans have probably contributed to the extinction of Australian native species in pre- and post-European colonisation times. Examine the extinct, endangered & critically endangered species (the *Red Book)* and link to causes of the reductions in these species numbers. Investigate the steps being taken to preserve species (including how to preserve habitat). Follow the development of the environmentalist movement following the publication of Rachel Carson's *Silent Spring (1962),* or the foundation of the Greenpeace organisation in 1971.
Maintaining biodiversity is an ethical issue with long term biological and/or environmental consequences. • Recognise that humans have an ethical obligation to prevent species extinction.	Investigate strategies that can be used to maintain biodiversity. Explore the role of quarantine laws in protecting native species. Research the impact of local, national, and global initiatives and organisations that focus on the preservation of biodiversity.

ASSESSMENT SCOPE AND REQUIREMENTS

All Stage 2 subjects have a school assessment component and an external assessment component.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 2 Biology:

School Assessment (70%)

- Assessment Type 1: Investigations Folio (30%)
- Assessment Type 2: Skills and Applications Tasks (40%)

External Assessment (30%)

Assessment Type 3: Examination (30%).

Students provide evidence of their learning through eight assessments, including the external assessment component. Students complete:

- at least two practical investigations, and one investigation with a focus on science as a human endeavour for the folio
- at least three skills and applications tasks
- one examination.

At least one investigation or skills and applications task should involve collaborative work.

It is anticipated that from 2018 all school assessments will be submitted electronically.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by:

- teachers to clarify for the student what he or she needs to learn
- teachers and assessors to design opportunities for the student to provide evidence of his or her learning at the highest possible level of achievement.

The assessment design criteria consist of specific features that:

- students should demonstrate in their learning
- teachers and assessors look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described in the list below.

The set of assessments, as a whole, give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Design of a biological investigation

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats

IAE3 Analysis of data and other evidence to formulate and justify conclusions

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of biological concepts

KA2 Application of biological concepts in new and familiar contexts

KA3 Demonstration of understanding of science as a human endeavour

KA4 Communication of knowledge and understanding of biological concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio (30%)

Students undertake at least two practical investigations and one investigation with a focus on science as a human endeavour. They inquire into aspects of biology through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical Investigations

As students design and safely carry out investigations, they develop and extend their science inquiry skills by formulating investigable questions and hypotheses, selecting, trialling, and using appropriate equipment, apparatus, and techniques, identifying variables, collecting, representing, analysing, and interpreting data, evaluating procedures and considering their impact on results, drawing conclusions, and communicating their knowledge and understanding of concepts.

Practical investigations may be conducted individually or collaboratively, but each student should present an individual report. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical report should include:

- introduction with relevant biology concepts, a hypothesis and variables, or investigable question
- materials/apparatus, method/procedure outlining trials and steps to be taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of procedures and data, and identifying sources of uncertainty
- conclusion.

The report should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

*The materials/apparatus, method/procedure outlining trials and steps to be taken, identification and management of safety and/or ethical risks, and results sections are excluded from the word count.

At least one practical investigation must give each student the opportunity to design the method.

Suggested formats for presentation of a practical investigation report include:

- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of biology with an emphasis on science as a human endeavour. This investigation focuses on at least one aspect of science as a human endeavour described on pages 46 and 47 and may draw on a context suggested in the topics being studied or explore a new context.

Students consider, for example:

- how humans seek to improve their understanding and explanation of the natural world
- how working scientifically is a way of obtaining knowledge that allows for the analysis of scientific claims, and also allows change in scientific theory in the light of new evidence. These changes may be due to technological advances.
- the role of social, ethical, and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically, and hence speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact and influence on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

Possible starting points for the investigation could include, for example:

- an article from a scientific journal (e.g. Cosmos)
- critiquing a blog or TED talk based on a biological impact
- an advertisement or a film clip in which a biological concept is misconstrued
- an expert's point of view
- a new development in the field of biological science endeavour
- the impact of a technique and its historical development
- concern about an issue that has environmental, social, economic, or political implications
- emerging biology-related careers and pathways
- changes in government funding for biology-related purposes, e.g. for scientific research into biotechnology, conservation planning, hormone use in food production, safe disposal of nuclear waste, biosecurity, water quality, greenhouse effect, energy supplies, disease control, health.

Based on their investigation, students prepare a scientific communication, which must include the use of scientific terminology and:

- an introduction to identify the focus of the investigation and how it links to science as a human endeavour
- relevant biology concepts or background
- an explanation of the impact or significance of the focus of the investigation, e.g. potential of new development, effect on quality of life, environmental implications, economic impact, intrinsic interest
- a conclusion with justification
- citations and referencing.

The communication should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

This communication could take the form of, for example:

- an article for a scientific journal
- a letter to the editor
- a report.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks (40%)

Skills and applications tasks require students to use their knowledge and understanding of relevant biological ideas, facts, and relationships in a range of tasks that may be:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

Students undertake at least three skills and applications tasks. Students may undertake more than three skills and applications tasks within the maximum number of tasks allowed in the school assessment component, but at least two should be under the direct supervision of the teacher. The supervised setting should be appropriate to the task. Each supervised task should be a maximum of 90 minutes of class time, excluding reading time.

A skills and applications task may require students to, for example: use biological terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically; and design an investigation to test a hypothesis.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key biological concepts and learning covered in the program, and to apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context. Tasks should also enable students to demonstrate science inquiry skills. Students use appropriate biological terms and conventions to explain links between biological concepts, and demonstrate an understanding of science as a human endeavor.

Skills and applications tasks may include:

- modelling or simulation
- a data interpretation exercise
- a multimodal product
- a practical assessment such as a 'completion practical' with associated questions
- an oral presentation
- an extended response
- a written assignment
- multiple-choice questions in combination with other question types
- short-answer questions.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

EXTERNAL ASSESSMENT

Assessment Type 3: Examination (30%)

Students undertake one 2½ hour examination.

Questions of different types cover all Stage 2 topics and the science inquiry skills. Some questions may require students to integrate their knowledge from more than one topic and show an understanding of science as a human endeavour as described on pages 46 and 47.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills, and understanding that teachers and assessors refer to in deciding how well a student has demonstrated his or her learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of each school assessment type, the teacher makes a decision about the quality of the student's leaning by:

- referring to the performance standards
- assigning a grade between A+ and E- for the assessment type.

The student's school assessment and external assessment are combined for a final result, which is reported as a grade between A+ and E-.

Performance Standards for Stage 2 Biology

	Investigation, Analysis and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed biological investigation. Obtains records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates discusses their effects on data.	Demonstrates a deep and broad knowledge and understanding of a range of biological concepts. Applies biological concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of biology coherently, with highly effective use of appropriate terms, conventions and representations.
B	Designs a well-considered and clear biological investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of biological concepts. Applies biological concepts mostly effectively in new and familiar contexts. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of biology mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear biological investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of biological concepts. Applies biological concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of biology generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a biological investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of biological concepts. Applies some biological concepts in familiar contexts. Identifies some aspect of science as a human endeavour. Communicates basic biological information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a biological investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of biological concepts. Attempts to apply biological concepts in familiar contexts. Shows some recognition of science as a human endeavour. Attempts to communicate information about biology.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (www.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement, in both the school assessment and the external assessment, are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 2 are available on the SACE website (www.sace.sa.gov.au)

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.edu.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website (www.sace.sa.edu.au).