Senior External Syllabus

Biology

Syllabus for the Senior External Examination

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Biology Syllabus for the Senior External Examination

This syllabus should be used for the first time in the 2007 Senior External Examination in Biology.

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Contents

1. A view of science and science education

Science is a social and cultural activity through which explanations of natural phenomena are generated. It incorporates ways of thinking that are creative and critical. Scientists have a deep conviction that the universe is understandable.

Explanations of natural phenomena may be viewed as mental constructs based on personal experiences. They emerge from a range of activities that may include observation, experimentation, imagination and discussion, and are achieved by considering the complexities of the universe at a level that can be understood. The evolution of scientific understandings has happened in definable episodes, with chance sometimes playing an important role.

Currently accepted scientific concepts, theories and models may be viewed as shared understandings that the scientific community perceive as viable in light of the available evidence and arguments presented, and that have a predictive value. New understandings are continually arising, and the scientific community may challenge, modify, or replace current understandings. This is an essential characteristic of science.

Candidates construct personal explanations of phenomena they experience in everyday life. One role of science education is to help candidates move from their personal constructions, which are at times discordant with scientific explanations, towards theories and models accepted by the scientific community. As candidates progress through their formal education, explanations of the phenomena they encounter increase in complexity, as does the sophistication of their observations.

Science candidates are encouraged to appreciate the social and cultural perspectives of science. They also participate in activities that help them construct explanations and recognise the nature of scientific understandings.

Through science education, candidates are encouraged to develop critical and creative thinking skills as well as scientific understandings. This will equip them to imagine alternative futures and make informed decisions about science and its applications. Such decisions will influence the wellbeing of themselves, other living things and their environment.

2. Rationale

Biology is the study of life in its many manifestations. It encompasses studies of the origin, development, diversity, functioning and evolution of living systems and the consequences of intervention in those systems.

Biology is characterised by a view of life as a unique phenomenon with fundamental unity. Living processes and systems have many interacting factors that make quantification and prediction difficult. An understanding of these processes and systems requires integration of many branches of knowledge.

The study of Biology provides candidates with opportunities to:

- gain insight into the scientific manner of investigating problems in the living world
- experience the processes of science, and that leads to the discovery of new knowledge
- develop a deeper understanding and aesthetic appreciation of the living world.

Participation in Biology enables candidates to engage in creative scientific thinking and to apply their knowledge in practical situations. The study of Biology will help candidates foresee the consequences of their own and society's activities on the living world. This will enable them to participate as informed and responsible citizens in decision-making processes, the outcomes of which will affect the living world now and in the future.

3. Global aims

Biology provides learning experiences that will allow candidates to further develop:

- a knowledge and understanding of the living world
- the capacity to identify, gather, manipulate and process information in the context of scientific endeavours, including field investigations
- the capacity to communicate effectively in various formats on biological issues
- an appreciation of the complexity and beauty of biological phenomena
- a recognition that Australian ecosystems have unique characteristics
- an appreciation that each type of organism, including *Homo sapiens,* occupies a unique position in the biosphere
- a sense of responsibility for the stewardship of the local and global environment
- an ability to apply biological understanding, skills and reasoning to present-day and emerging issues.

4. General objectives

4.1 Introduction

The General objectives are derived from the interaction of the Global aims, Rationale, and A view of science and science education.

The general objectives of the syllabus are categorised as:

- *Understanding biology*
- *Investigating biology*
- *Evaluating biological issues*
- *Attitudes and values*.

Learning through each of the general objectives is developed through learning experiences and activities that range from simple to complex in their challenge to candidates. Participation in these learning experiences requires candidates to present and communicate ideas and information.

Candidates are required to communicate ideas and information using genres, terminology and conventions (linguistic, mathematical, graphic and symbolic) appropriate to biology.

At all times, candidates are to be aware of safety issues and use safe scientific practice.

The *Attitude and values* objective relates to the affective elements that permeate each of the other three objectives. This objective is not directly assessed in awarding exit levels of achievement. The objectives of *Understanding biology, Investigating biology*, and *Evaluating biological* issues are linked to the exit criteria of this syllabus.

4.2 Understanding biology (UB)

This objective provides opportunities for candidates to demonstrate a knowledge and understanding of the key concepts and ideas of biology. Candidates will be required to acquire, construct and communicate knowledge and understanding of the ideas, concepts and theories of biology.

Candidates should:

1. recall ideas, concepts and theories of biology
2. describe biological ideas, concepts and theories applied to a range of situations
3. apply and link ideas, concepts and theories to explain phenomena in a range of situations.

4.3 Investigating biology (IB)

This objective provides opportunities for candidates to access, collect, derive and interpret quantitative and qualitative biological data. Candidates will be required to critically and creatively question, observe, construct ideas, make choices, analyse data, make decisions and solve problems to demonstrate the processes involved in biological investigation.

Candidates should:

1. identify and formulate questions and hypotheses for investigations and research
2. design, manage and carry out experimental and non-experimental investigations
3. develop skills and processes required to collect, organise, interpret, model and present primary and secondary data
4. analyse data gathered from investigations
5. make judgments and draw conclusions pertaining to the validity of an investigation.

4.4 Evaluating biological issues (EBI)

This objective aims to develop in candidates the ability to embrace current biological understandings and ideas to evaluate the effects of their application on present-day and future society.

Candidates will be required to gather information, predict outcomes, and make and communicate informed decisions about the effects of human intervention on biological systems.

Candidates should:

1. recognise relevant past and present scientific and social issues
2. explain the explicit and implicit meanings of information selected from a variety of sources
3. evaluate and assess the reliability, authenticity, relevance, accuracy and bias of the sources and methods of the collection of information
4. justify decisions and develop future scenarios based on the interpretation and analysis of current information.

4.5 Attitudes and values (AV)

The focus of this objective is for candidates to develop heightened levels of sensitivity to the implications of biology for individuals and groups in society. It refers to the feelings, dispositions and ways of thinking about questions and issues in the field of study. This objective requires candidates to consider attitudes and values in making decisions related to biology. Through this process, candidates should develop attitudes and values to:

1. understand that science is a human endeavour and has limitations
2. demonstrate collegiality and cooperation
3. retain a commitment to scientific reasoning, openness to new ideas, intellectual honesty, and respect for evidence
4. appreciate the contribution of biology to local, national and international issues
5. acknowledge responsibility when making decisions about the use of biological information
6. develop respect and appreciation for the natural world and minimise human impact on the environment.

5. Organisation

5.1 Organising principles

The syllabus provides the conceptual basis on which tuition in Biology may be constructed but does not limit the approach taken. Candidates should explore topics and develop understanding of the concepts.

Increasing complexity in both scope and depth of subject matter should be developed throughout the study of Biology. While the scope and depth of treatment of particular concepts is the decision of the teaching centre, increasing complexity should be reflected in selected learning experiences. The local community should be explored for resources that would enrich the course.

Time allocation

For teaching centres preparing candidates for the external examination the recommended number of hours for tuition in the subject developed from this syllabus is 130 to 200 hours. The time allocation suggested provides a guide for the effective planning of learning experiences.

Time allocation depends on the method of study. Candidates who elect to study without systematic tuition must organise their time according to syllabus requirements and individual circumstances.

5.2 Structure of the subject

Study of this subject should reflect the interconnectedness of principles of biology, key concepts, key ideas and topics.

The key concepts should be expanded through the key ideas that are developed through the learning experiences in the topics. Topics should be approached using a combination of subject matter, issues and experimental investigations. Suggestions of experimental investigations and issues have been included in the topic information.

5.2.1 Framework for study

Principles of Biology

The syllabus provides a framework for the development of understandings using topics rather than lists of content. The topics presented are inherent in the principles of Biology, which are:

- **Survival** of species is dependent on individuals staying alive long enough to **reproduce**.
- At every level of organisation in the living world **structure and function** are interrelated. Each level of organisation in the living world has its own unique aspects and there is continual interaction of structure and function between these levels.
- **Continuity and change** occurs at all organisational levels in the living world. Changes may be cyclical or directional. The continuity of life is a balance between all the change processes.

Key concepts

The study of Biology in this syllabus allows for selection of learning experiences relevant to the needs and interests of candidates. It is expected that:

- all key concepts are considered as equally significant
- aspects of more than one key concept will be included in a topic
- aspects of each key concept will be included in more than one topic
- opportunities to demonstrate evidence of candidates' understanding of each key concept will be provided in the examination papers.

Table 1 Key concepts

1. Cells are the functioning units of all living things.
2. Multicellular organisms are functioning sets of interrelated systems.
3. Organisms live an interdependent existence in environments to which they are adapted.
4. A variety of mechanisms result in continual change at all levels of the natural world.
5. *There are processes that maintain dynamic equilibrium at all organisational levels.
6. There are mechanisms by which characteristics of individuals in one generation are passed on to the next generation.

** Key concept #5 should be integrated into all topics.*

Key ideas

Associated with the concepts of each topic are key ideas, which reflect the complex nature of the concepts. The key ideas in the following table indicate the depth and scope of the concepts. These key ideas should be drawn upon to design learning experiences that candidates undertake as they construct understandings of concepts.

Table 2 Key ideas

1. Cells have a chemical composition that must be maintained for the continued life of the cell.
2. Organelles contribute to the structure and functioning of eukaryotic cells.
3. There are different types of cells and the ways they are organised influences their functioning.
4. Energy required by all living things is obtained in different ways.
5. Cell division is an integral part of growth and reproduction.
6. The set of systems comprising an organism enables it to function in its environment.
7. All systems are interrelated and interdependent.
8. Systems of the body work together to maintain a constant internal environment.
9. Different types of multicellular organisms have different roles in an environment.
10. Malfunctioning in one system or part of a system may affect the whole organism.
11. The external features and internal functioning of organisms together enable an organism to obtain its needs.
12. Abiotic and biotic factors in an environment influence the size of populations and the composition of communities.
13. Energy and matter move within ecosystems.
14. Human actions have significant impacts on interactions within an environment.
15. Different organisms perform different interdependent roles in an ecosystem.
16. An organism has adaptations specific to its environment.
17. Living things employ a variety of reproductive strategies.
18. Human understanding of the mechanisms of reproduction and DNA structure and function has led to intervention in natural processes.
19. Theories of evolution by natural selection can be used to explain speciation and changes in organisms through time.
20. The activity of organisms changes the environment.
21. Evidence shows that organisms and ecosystems change through time.
22. In most organisms coded instructions within the DNA molecule account for their inherited characteristics.
23. During reproduction DNA is passed from parent(s) to offspring.
24. The genetic variations within a population determine its long-term survival.
25. Evolutionary processes acting on the gene pools of populations have given rise to diversity of organisms.
26. Humans group organisms in a variety of ways to make sense of diversity and to aid communication.

Topics

The topics are a group of learning experiences incorporating the subject matter organised around the development of the general objectives and the key concepts.

Table 3 Topics

1. Cell structure and function
2. Physiology of organisms
3. Organisms and ecosystems
4. Continuity of life
5. Diversity and evolution.

Table 4 Suggested relationships of the topics to key concepts and key ideas

Topics	Key concepts	Key ideas
1. Cell structure and function	1. Cells are functioning units of all living things. 5. There are processes that maintain dynamic equilibrium at all organisational levels.	1. Cells have a chemical composition that must be maintained for the continued life of the cell. 2. Organelles contribute to the structure and functioning of eukaryotic cells. 3. There are different types of cells and the ways they are organised influences their functioning. 4. Energy required by all living things is obtained in different ways. 5. Cell division is an integral part of growth and reproduction. 6. The set of systems comprising an organism enables it to function in its environment. 11. The external features and internal functioning of organisms together enable an organism to obtain its needs. 23. During reproduction DNA is passed from parent(s) to offspring. 26. Humans group organisms in a variety of ways to make sense of diversity and to aid communication.
2. Physiology of organisms	2. Multicellular organisms are functioning sets of interrelated systems. 5. There are processes that maintain dynamic equilibrium at all organisational levels.	4. Energy required by all living things is obtained in different ways. 6. The set of systems comprising an organism enables it to function in its environment. 7. All systems are interrelated and interdependent. 8. Systems of the body work together to maintain a constant internal environment. 10. Malfunctioning in one system or part of a system may affect the whole organism. 11. The external features and internal functioning of organisms together enable an organism to obtain its needs. 16. An organism has adaptations specific to its environment.
3. Organisms and ecosystems	3. Organisms live an interdependent existence in environments to which they are adapted. 4. A variety of mechanisms result in continual change at all levels of the natural world. 5. There are processes that maintain dynamic equilibrium at all organisational levels.	4. Energy required by all living things is obtained in different ways. 6. The set of systems comprising an organism enables it to function in its environment. 7. All systems are interrelated and interdependent. 9. Different types of multicellular organisms have different roles in an environment. 11. The external features and internal functioning of organisms together enable an organism to obtain its needs. 13. Energy and matter move within ecosystems. 14. Human actions have significant impacts on interactions within an environment. 15. Different organisms perform different interdependent roles in an ecosystem. 16. An organism has adaptations specific to its environment. 20. The activity of organisms changes the environment. 21. Evidence shows that organisms and ecosystems change through time. 23. Abiotic and biotic factors in an environment influence the size of populations and composition of communities. 26. Humans group organisms in a variety of ways to make sense of diversity and to aid communication.

4. Continuity of life	6. There are mechanisms by which characteristics of individuals in one generation are passed on to the next generation. 1. Cells are the functioning units of all living things. 5. There are processes that maintain dynamic equilibrium at all organisational levels.	1. Cells have a chemical composition that must be maintained for the continued life of the cell. 5. Cell division is an integral part of growth and reproduction. 6. The set of systems comprising an organism enables it to function in its environment. 7. All systems are interrelated and interdependent. 16. An organism has adaptations specific to its environment. 17. Living things employ a variety of reproductive strategies. 18. Human understanding of the mechanisms of reproduction and DNA structure and function has led to intervention in natural processes. 22. In most organisms coded instructions within the DNA molecule account for their inherited characteristics. 23. During reproduction DNA is passed form parent(s) to offspring. 24. The genetic variations within a population determine its long-term survival.
5. Diversity and evolution	4. A variety of mechanisms result in continual change at all levels of the natural world. 3. Organisms live an interdependent existence in environments to which they are adapted.	3. There are different types of cells and the ways they are organised influence their functioning. 6. The set of systems comprising an organism enables it to function in its environment. 7. All systems are interrelated and interdependent. 10. Malfunctioning in one system or part of a system may affect the whole organism. 12. Abiotic and biotic factors in an environment influence the size of populations and the composition of communities. 14. Human actions have significant impacts on interactions within an environment. 15. Different organisms perform different interdependent roles in an ecosystem. 18. Human understanding of the mechanisms of reproduction and DNA structure and function has led to intervention in natural processes. 19. Theories of evolution by natural selection can be used to explain speciation and changes in organisms through time. 20. The activity of organisms changes the environment. 21. Evidence shows that organisms and ecosystems change through time. 24. The genetic variations within a population determine its long-term survival. 25. Evolutionary processes acting on the gene pools of populations have given rise to diversity of organisms.

6. Topics

The following information provides candidates with intended focus and subject matter for each topic. Suggested learning experiences are also provided.

For each of the five topics candidates are expected to develop an understanding of the concepts outlined and relate these to the specific contexts and/or environments in which they are studying.

Topic 1 — Cell structure and function

Focus

The composition, structure and functioning of cells leads to an understanding of the relationship of cellular processes in the life of complex organisms.

Subject matter

Prokaryotic and eukaryotic cells differ in their structure.

Organelles contribute to the structure and function of cells (e.g. cell membrane, cell wall, nucleus, nucleolus, vacuole, lysosome, Golgi complex, endoplasmic reticulum, ribosome, plastid, and mitochondrion).

There are structural similarities and differences between the cells of higher plants and animals, many of which can be observed using an optical microscope.

The major groups of chemical compounds in cells are carbohydrates, lipids, nucleic acids, proteins, and water containing dissolved substances. Each group contributes to the functioning of the cell and has a unique basic structure and composition. (Details of molecular structure are not required.)

Cellular activities require energy. Light-dependent and light-independent reactions of photosynthesis and aerobic and anaerobic respiration are important processes involving energy. These processes involve enzyme action and adenosine triphosphate (ATP).

The structure of the cell membrane regulates the ways substances move into and out of cells (osmosis, diffusion, active transport, and exo- and endocytosis).

Tissue development and cell replacement involve the process of mitosis.

The function of cells relates to their structure (e.g. size, shape, organelle and chemical composition and location).

Learning experiences — Cell structure and function

The following learning experiences, which include suggested issues and experimental investigations, may be used to develop the general objectives and key concepts relating to this topic:

- Observe a variety of cells in order to make structural and functional comparisons between them.
- Investigate chemicals present in cells, e.g. starch, glucose, cellulose, proteins, lipids to draw conclusions about their role in living matter.

- Factors that could be varied are temperature, surface area and pH, concentrations of enzymes and substrate.
- Investigate the structure and functioning of the cell membrane by observing and evaluating the effect of various environmental conditions.
- Analyse data to predict the effect of varying environmental conditions on cellular energy transformations (photosynthesis, respiration).
- Model and analyse the stages of the cell cycle (mitosis and cytokinesis).
- Critically evaluate the scientific validity and bias of a media presentation of a significant biological issue.

Issues

The process of scientifically evaluating topical issues may be explored through the following examples:

- processes relating to effect of drugs on cellular processes
- the development of artificial membranes and their use
- stem cells
- tissue culture (horticulture, skin graft)
- other relevant biological issues.

Experimental investigations

At least one experimental investigation should be explored. The following are suggestions:

- Design and carry out an investigation to determine a relationship between environmental conditions and enzyme activity.
- Design and carry out an investigation into the relationship between surface area and volume and the implications this has for cells (diffusion, osmosis).

Topic 2 — Physiology of organisms

Focus

Organisms obtain, transform and store energy and materials available from their surroundings. This requires the integration of physiological systems in order to sustain the life of a complex, multicellular organism. Specialised structures and processes allow organisms to respond to environmental demands. Emphasis should be placed on vascular plants and mammals, e.g. humans.

Subject matter

There are specialised structures associated with obtaining nutrients, transport, gas exchange and excretion. Organisms have adaptations that enable them to function in different types of environment.

Processes such as transpiration and translocation move materials within vascular plants. Diffusion, osmosis and active transport are processes common to all organisms and are sensitive to environmental conditions.

The integration of structures and processes is essential for the functioning of the whole organism.

Stimulus response and feedback mechanisms are important for the integration and coordination of processes.

Homeostasis is the coordination and control of various body processes to maintain a dynamic equilibrium in the internal environment.

Malfunctioning of structures and/or processes will have varying effects on the functioning of the system and the organism as a whole.

Learning experiences — Physiology of organisms

- Use microscopes to examine plant root, stem and leaf section to relate cell structure to function.
- Analyse data relating to observations of the movement and water loss in plants.
- Investigate plant responses to environmental factors, e.g. phototropism, geotropism, apical dominance. Relate this to hormone action.
- Investigate plant and animal adaptations to the specific environment and conditions (through participation in the field, using photographs or ICT).
- Perform dissections to establish relationships between systems (actual or virtual plant and/or animal specimens).
- Analyse second-hand data to make inferences regarding the function of the kidney as an organ of homeostasis.
- Analyse the nutritional value and evaluate the possible consequences of prolonged use of two currently promoted diets.
- Infer the possible causes and effects of a system or organ malfunction, e.g. heart attack, stroke, diabetes.
- Investigate a mechanism involving a stimulus and response of an organ to explain how this contributes to the maintenance of a constant internal environment, e.g. osmoregulation and levels of sugar.
- compare plant and animal structures and processes to determine commonalities.

Issues

The process of scientifically evaluating topical issues such as the following may be explored:

- organ transplantation
- artificial organs and tissues, robotics
- lifestyle diseases
- drugs and sport
- irradiation of fresh produce
- biological research projects and their implications (social, financial, political, etc.).

Experimental investigations

At least one experimental investigation should be explored. The following are suggestions:

- Investigate and analyse data relating to factors affecting photosynthesis, e.g. carbon dioxide concentration, light intensity and wavelength, and temperature.
- Design experiments to investigate how transpiration rate varies with different environmental conditions, e.g. temperature, relative humidity and wind speed.
- Develop and test hypotheses related to the cause and effect of physiological relationships, e.g. effect of exercise on body physiology.

Topic 3 — Organisms and ecosystems

Focus

There are basic principles associated with the functioning of ecosystems and the relationships between organisms, populations and communities in different ecosystems. These principles should be applied to the Australian context in order to recognise the potential and actual impact of human activity on organisms, populations, communities and ecosystems. These understandings can be applied at a global level.

Subject matter

Organisms exhibit different structural, physiological and behavioural adaptations in different environments (biotic, abiotic, aquatic, terrestrial).

The population growth rate and distribution of a species is determined by the available resources, physical environment, its own characteristics and the activities of other organisms.

Special associations may occur between organisms within a community (food webs, predation, parasitism, mutualism, competition).

Changes in communities result from changes in the surroundings and members of the community interacting with each other and with the abiotic environment (succession and seasonal changes).

An ecosystem consists of both living and non-living components. Energy flows through ecosystems and matter cycles within ecosystems (nitrogen, carbon, water).

By replacing natural ecosystems with agricultural and/or urban ecosystems, human activity has altered the natural flow of energy and matter (thermal pollution, agricultural and domestic runoff).

Changes in ecosystems can occur as a result of natural processes and human activity (fire, salination, eutrophication and introduced species).

An understanding of the various interactions within ecosystems is an integral part of environmental management.

Learning experiences — Organisms and ecosystems

The following learning experiences may be used to develop the general objectives, and key concepts relating to this topic:

- Select a variety of plants and/or animals from a particular environment and determine structural, physiological and behavioural adaptations that allow these organisms to survive in their environment.
- Investigate populations and/or communities to determine how they change over time.
- Collect and interpret abiotic and biotic data of one or more ecosystems.
- Design and perform an investigation to determine the particular abiotic and/or biotic preferences of a species (transect of plants from shade to sunlight area, feeding preferences of animals).
- Construct food webs from data relating to the feeding relationships in an ecosystem.
- Use diagrams, flow charts and/or computer simulations to model the movement of matter and energy within ecosystems.

- Undertake a case study of an introduced species to determine its impact on a local ecosystem (hard-hoofed animal, camphor laurel trees in waterways).
- Investigate the land and water management practices in your local area and relate these to environmental concerns.
- Consult with Aboriginal and Torres Strait Islander elders and/or study journals, videos and other resources to obtain information to report on ways in which Aboriginal and Torres Strait Islanders describe ecosystem relationships, predict cyclical events and manage an ecosystem.

Issues

The process of scientifically evaluating topical issues such as the following may be explored:

- monocultures (pine tree plantations, cotton growing)
- hunting sharks
- land filling of swamplands/mangroves
- water quality and availability
- soil erosion control
- pest and weed control
- land clearing of grazing areas
- dumping of toxic and nuclear waste.

Experimental investigation

At least one experimental investigation should be explored. The following is a suggestion:

- analysis of first-hand data collected during the field study.

Topic 4 — Continuity of life

Focus

Asexual and sexual reproduction are the mechanisms that maintain the continuity of life. Characteristics that are transferred from one generation to the next maintain species integrity, allow variations between individuals of a species and provide the basis for evolution through mutation. Environmental factors impact on the mode of reproduction and phenotypic expression of genes in organisms. Scientific and technological developments that allow intervention in the reproductive cycle and genetic manipulation of organisms have ethical and social implications. Emphasis should be placed on flowering plants and humans while developing an awareness of other organisms.

Subject matter

Asexual reproduction produces similar offspring while sexual reproduction results in variation.

Both internal and external fertilisation are associated with a range of different reproductive strategies for survival in different environmental conditions.

Meiosis occurs at some stage in the life cycle of sexually reproducing organisms.

Plants and animals have specialised reproductive structures.

Pollination and fertilisation in flowering plants may result in seed development.

Reproductive cycles in mammals are regulated by hormone feedback mechanisms.

The development of the fertilised egg into a new individual and its growth involves mitotic division in multicellular organisms.

A variety of technologies is applied to either inhibit or facilitate human reproduction.

Some patterns of inheritance can be predicted by applying knowledge of dominant and recessive genes, monohybrid and dihybrid crosses, incomplete dominance, co-dominance, sex determination and sex linkage.

Environmental factors can affect the phenotype and, by causing mutations, affect the genotype.

Knowledge of the structure of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) has contributed to an understanding of genes, DNA replication and mutation.

DNA, messenger-RNA, transfer-RNA and ribosomes all play a role in protein synthesis in cells.

Genotypes can be manipulated using a variety of technologies, for example recombinant DNA technology.

Learning experiences — Continuity of life

The following learning experiences may be used to develop the general objectives and key concepts related to this topic:

- Collect and analyse information on different reproductive strategies used by a variety of organisms and relate these to the type of reproduction and the environmental conditions of the organism.
- Compare the structures and functions of the human reproductive system with those of a pea plant.
- Model and compare the stages of meiosis and mitosis (e.g. using coloured wool/pipe cleaners as chromosomes, diagrams or computer simulations).
- Investigate the organs of the reproductive system to appreciate the interrelationship of the individual structures (e.g. using interactive CD–ROMS, videos, plastic 3D models or dissections).
- Using second-hand data, develop a concept map that links the ovarian and uterine cycles to positive and negative feedback in the hormonal system in the human female.
- Compare the reproductive strategies of a variety of vertebrates and relate differences to environmental conditions (e.g. fish, frog, viviparous snake, bird, kangaroo, dolphin).
- Use computer and other simulation to investigate and analyse patterns of inheritance e.g. beads, pipe cleaners, plastic discs.
- Critically review a journal article on reproductive technologies or gene manipulation to make informed decisions about implications of its use.
- Investigate various types of mutation to determine the effect on protein synthesis or survival of the individual.
- Describe how reverse transcription can be used to determine the DNA base sequence and/or to locate the gene position on a chromosome for a particular protein.
- Analyse a DNA base sequence to determine the amino acid sequence in a polypeptide chain e.g. DNA fingerprinting.

Issues

The process of scientifically evaluating topical issues such as the following may be explored:

- synchronicity of the menstrual cycle in institutionalised females e.g. boarding schools, girls' homes, jails.
- public health issues related to reproduction e.g. smoking during pregnancy, substance abuse, contraception and breastfeeding.
- treatment of infertility and the associated consequences
- cloning
- transgenic organisms
- breeding programs in horticulture, aquaculture and agriculture.

Experimental investigation

At least one experimental investigation should be explored during the course. The following is a suggestion:

- investigate the monohybrid ratio by growing barley seeds heterozygous for albinism.

Topic 5 — Evolution and diversity

Focus

Evidence from a variety of sources indicates that evolution has occurred. The central concept of natural selection provides a scientific model for the emergence and extinction of species. The theory of evolution can explain the great diversity and commonalities of life on earth, past and present. Organisms can be classified based on their similarities and differences.

Subject matter

Evidence drawn from diverse fields of science indicates that the earth is of great age.

Evidence for evolution is found in many different fields of modern science including palaeontology, comparative anatomy, embryology, genetics and molecular biology.

Although various scientific attempts had been made to outline mechanisms accounting for the observed phenomenon of evolution (e.g. by Lamarck), it was Darwin's theory of natural selection that gained widespread and enduring support within science.

The theory of natural selection outlines a mechanism that accounts for the observed phenomenon of biological evolution.

Modern discoveries have contributed to a deeper understanding of the origins of genetic variation, the alteration of gene frequencies within populations and the processes leading to speciation.

Complex organisms have evolved from simpler organisms.

The hierarchical classification used in biological science has the species concept as its basis and provides an evolutionary history (phylogeny) of organisms.

International conventions govern the naming and classification of species.

The naming of species and their classification changes with current interpretation of data.

Distinctive characteristics enable major groups of organisms to be distinguished from each other (monerans, protists, fungi and representative phyla of plants and animals).

The emergence of adaptations enables organisms to colonise diverse environments.

Human activities can affect the course of evolution and have had a major impact on biodiversity.

Learning experiences — Evolution and diversity

- Construct a timeline to illustrate evolutionary events.
- Gather information from various lines of evidence to show that evolution occurs.
- Model natural selection using computer simulations, cards or disks to show how gene frequencies can change over time.
- Construct a sequence of steps for the emergence of adaptations to demonstrate an understanding of the process of natural selection.
- Analyse the various ways in which speciation may occur to identify common elements.
- Analyse classification to reveal the evolutionary relationships between selected organisms.
- Visit a botanical garden, museum, park, state forest, creek or foreshore to observe species diversity.
- Use and construct keys/field guides to identify local flora and fauna.
- Gather information pertaining to the characteristics and breeding behaviour of different organisms to determine whether they belong to the same species.
- Gather information to form a justified opinion on the concept of interbreeding to save a species from extinction (e.g. red and grey wolves).

Issues

The process of evaluating biological issues (section 4.3) is more important than the specific content of the issue. Aspects of the following could be explored:

- resistance to pesticides and antibacterial drugs
- bioethics of the genetic engineering of ancient life forms
- preservation of biodiversity
- bacteria and bioremediation
- impact of artificial selection.

Experimental investigation

At least one experimental investigation should be explored. The following is a suggestion:

- design an investigation to analyse the variation within a species or to illustrate the evolution of resistance to a pesticide

7. Learning experiences

Learning experiences provide the bridge between the general objectives of the syllabus and achievement of standards as demonstrated through the external examination. This section of the syllabus provides suggestions for a range of learning experiences. Candidates' backgrounds, the role of language, the importance of field work and practical work, and the resources available should be considered in the selection of learning experiences.

Study in Biology should provide learning experiences that will contribute to the development of individuals who:

- can recognise relevant issues and pose questions that are related to science or technology
- are able to associate real-world situations with appropriate scientific concepts and principles
- can identify sources of relevant information and/or data
- are aware of, and are skilled in using, scientific methods for extracting and/or collecting information or data
- can manipulate data and information in ways appropriate to the task
- make decisions based upon the best available information
- through their actions, communicate their competence in and understanding of the abilities listed above.

A broad range of learning experiences should be used with each topic. The following suggestions for learning experiences are neither prescriptive nor exhaustive:

- collaborative learning, planning and organising activities, and solving problems
- laboratory activities and experiments
- library research
- assignment work
- constructing models
- using information technology
- classroom debates
- teacher explanation and questioning
- excursion and field work
- film, video and slide audiovisual observation
- computer software simulation
- case studies or surveys
- media presentations
- independent research study
- solving problems as an individual or member of a team
- searching the internet.

Relevance of real-world study

Issues explored should be relevant to society in real-world situations. They may integrate contexts, themes and problem-based learning so candidates can engage in real and intellectual inquiry while mastering important subject knowledge and understandings.

Success in dealing with problems and challenges in everyday life and work depends on developing and integrating a range of abilities, such as being able to:

- comprehend basic concepts and terms, in the areas of number, space, probability, statistics and measurement
- extract, convert or translate information given in numerical forms, diagrams, maps, graphs or tables
- use calculators and computers
- use skills or apply concepts from one problem or topic to another.

Within appropriate learning contexts and experiences in the subject, candidates should have opportunities to revise, maintain and extend quantitative skills and understandings. Biology candidates will usually be required to apply basic mathematical concepts learned in other subjects.

7.1 Language in Biology

The language characteristics of individuals and groups, the varieties of English used, and the ways in which candidates communicate, all influence the nature of learning Biology.

Candidates should become scientifically literate and be able to decipher technical articles in journals, books and magazines. Candidates should understand and use suitable scientific terms and phrases wherever the need arises so they may interpret technical manuals, catalogues, data sheets, etc. To achieve understanding of scientific terms, it may be necessary for candidates to develop their own glossaries as they study.

Learning experiences must be based on a range of sources that will contribute to producing scientifically literate adults. Candidates should use language effectively for several purposes in different contexts and for a variety of audiences. Candidates should prepare and present communications in a range of forms and mediums. Candidates should take part in learning experiences that involve them in:

Drawing upon sources of information, such as:	Using language for the purposes of:	Presenting information in forms such as:
observations	restating information	laboratory/field notes
demonstrations	reporting results	formal reports
experiments	giving instructions	letters
textbooks	formulating a hypothesis	abstracts
handbooks of data	designing an experiment	précis
manuals of procedures	explaining a relationship	reviews
product brochures	arguing a proposition	oral presentations
specification sheets	proposing action	seminars
computer files	defending a position	discussions
journal articles	justifying a stand	demonstrations
media	evaluating an argument	charts
broadcast media	developing an idea	graphs
advertisements	interpreting a theory	sketches
videos or films	persuading	models
lectures	making conclusions	photographs
interviews	following instructions	electronic media
discussions	predicting the results of an experiment	
the internet	evaluating scientific arguments	

7.2 "Theory into practice"

Applications of biological knowledge relate to the natural world and the environment that humans have created. Biological investigations can be conducted in the field or the education environment.

Field work provides candidates with opportunities to experience, at first hand, some ecological principles, and candidates gain an appreciation of the complexity and beauty of a natural ecosystem. They also have opportunities to collect primary data that they can analyse and integrate with further ecological studies.

Field work could also provide candidates with opportunities to gather information about the work undertaken by biologists and to make links between theory and its applications.

Practical work enables candidates to develop the skills of investigation, data collection and analysis.

7.2.1 Field work

Field work is a fundamental part of the course.

Candidates should have the opportunities to undertake investigations that ideally involve a minimum of 10 hours in the field, excluding any preparatory work or follow-up activities as well as travelling time. Field work should be integrated with the study of the key concepts to help candidates better understand biological phenomena. It should provide candidates with the opportunity to observe and experience, at first hand, the operation of basic biological principles in real-life situations.

The objectives of field work would depend on the site chosen and the concepts being developed. Some possible venues for field work include:

- natural ecosystems
- museum
- university
- research institutions
- botanic gardens
- aquaria
- terraria
- school grounds
- hospitals.

Field work — 10 hours spent in the field
- at least 5 hours — natural ecosystems
- remainder can be developed to suit interests of candidates.

Artificial ecosystems such as botanic gardens are rather limited in their scope. *It is recommended, therefore, that candidates spend at least five hours studying natural ecosystems*. As part of their study of natural ecosystems it is strongly recommended that all candidates use:

- techniques for identifying organisms e.g. keys and field guides
- sampling techniques e.g. traps, quadrats and transects
- methods to measure environmental data e.g. pH of water and soil, salinity, temperature and availability of light.

The collection of biological material should be minimised to avoid damage to the environment and alternative means of gathering information should be examined, such as photography, digital imaging, video and drawing.

7.2.2 Practical work

Practical work is an integral part of this subject. Many concepts and ideas are better understood after first-hand observation and investigation. While no laboratory is specified, a significant amount of time should be spent working with biological materials. As well as carrying out laboratory exercises designed to illustrate particular concepts, candidates should be able to design their own controlled experiments to test hypotheses and write reports of their investigations.

Candidates should be given opportunities to develop concepts using an investigative approach. They should make observations, formulate hypotheses, design experiments, use equipment, collect and organise data, and draw conclusions. They should observe workplace health and safety standards.

Manipulative skills are fundamental to an effective scientific investigation and relate to the ability of candidates to operate scientific and experimental equipment proficiently and safely. Consequently, manipulative skills should be developed as part of normal day-to-day laboratory activities.

The following list outlines the skills that are fundamental to Biology:

1. prepare wet-mount slides and use a microscope to observe specimens
2. dissect specimen material to observe structure and infer function
3. use appropriate methods and equipment to measure environmental factors
4. handle specimens of living material responsibly and ethically
5. record observations of biological specimens, e.g. sketch/draw/photograph/video
6. use appropriate equipment to perform experiments to demonstrate biological phenomena, e.g. measure the rate of transpiration, demonstrate factors affecting photosynthesis, test food materials for their chemical components.

7.2.3 *Animal Care and Protection Act 2001*

Animal welfare

The Animal Care and Protection Act 2001 and the accompanying Animal Care and Protection Regulation 2002 govern the treatment and use of all animals in Queensland. The Department of Primary Industries (DPI) is responsible for enforcing the legislation. The purpose is to prevent animal suffering, to improve the welfare of animals and to ensure all use of animals for scientific purposes is justified, open and accountable. The definition of "scientific purposes" includes activities for the purposes of demonstration and teaching. The legislation covers animals described as "any live vertebrate, and includes live prenatal or prehatched creatures in the last half of gestation or development." Further details of the categories covered by the legislation can be obtained from the DPI website under "What is an animal?" http://www2.dpi.qld.gov.au/animalwelfare/9713.html

The Act also requires compliance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes. The current version at the time of printing is the 7th edition (2004) which can be downloaded from http://www.nhmrc.gov.au/publications/synopses/ea16syn.htm.

National codes of practice are available for most livestock industries, and outline acceptable standards of husbandry and management. There are also codes covering areas such as transporting livestock, saleyards and abattoirs. In Queensland, the national livestock codes are used as the minimum standard.

If you intend to use animals for scientific purposes (which includes teaching), you must do the following to comply with the Act:

1. You (or your employing institution) must register with the DPI and nominate the Animal Ethics Committee (AEC) that will assess your animal use.
2. Ensure all animal use is approved by the AEC before the activity.
3. Provide an annual report to the DPI of activities in which animals are used.

An employer may register with the DPI as a "user of animals for scientific purposes" to cover employee activities requiring the use of animals for scientific purposes. An animal ethics application must be made to the AEC for each "use of animals" or "type of use of animals" for a series of similar events. AECs may approve activities that are frequently repeated in a school program. Approval can be sought for a three-year period but activities must be reported annually to the AEC.

Employing authorities are considering ways in which they can support schools in complying with requirements. You should check with your employing authority for details of any guidelines or processes in place to help you meet the requirements of the legislation.

7.3 Workplace health and safety

Biology is a practical science. A significant amount of time should be devoted to practical experiences in the laboratory. These practical experiences expose candidates to a variety of hazards from corrosive and poisonous substances to injury from glass and hot objects. Besides a teacher's duty of care that derives from the *Education (General Provisions) Act 1989*, there are other legislative and regulatory requirements, for example the *Workplace, Health and Safety Act 1995*, that will influence the nature and extent of practical work.

All practical work must be organised with candidates' safety in mind. In Biology, many activities are associated with handling biological materials including live animal and plant specimens, micro-organisms, and materials for dissection that expose teachers and candidates to health hazards.

The current science safety requirements are clearly explained in *Workplace Health and Safety Guidelines — Curriculum — Core Module*, on the following website:
http://education.qld.gov.au/corporate/doem/healthsa/hs-10000/hs-10000.html

It is the responsibility of the teaching centre to ensure that their practices meet current guidelines.

8. Assessment

8.1 Summative assessment

8.1.1 Format of the external examination

The external examination will consist of two papers.

Each paper will:

- have 10 minutes perusal time
- have a duration of up to 3 hours
- cover the three general objectives (see section 4) through the exit criteria (section 8.2).

Each paper may include:

- multiple choice questions
- short answer questions
- extended response items.

Candidates should be able to provide responses to questions about the processes of experimental investigation and issues.

Candidates will not have access to text materials during either of the examination papers. Candidates may be required to bring in specific/experimental results for deeper analysis. Each year, the chief examiner will confirm the length of each examination paper and provide advice about additional conditions such as equipment, materials, readings, or the like, that will be required.

In the examination the full range of exit criteria will be addressed through the key concepts. All key concepts should have been covered through the subject matter, learning experiences, issues and experimental investigations of the topics.

8.2 Exit criteria

The following exit criteria will be used in making judgments about a candidate's level of achievement in Biology.

Criterion 1: *Understanding biology*

Criterion 2: *Investigating biology*

Criterion 3: *Evaluating biological issues***.**

Understanding biology (UB)

This criterion includes:

1. recalling ideas, concepts and theories of biology
2. describing biological ideas, concepts and theories applied to a range of situations
3. applying and linking ideas, concepts and theories to explain phenomena in a range of situations.

Investigating biology (IB)

This criterion includes:

1. identifying and formulating questions and hypotheses for investigations and research
2. designing experimental investigations
3. organising, interpreting, modelling and presenting data
4. analysing data
5. making judgments and drawing conclusions pertaining to the validity of an investigation.

Evaluating biological issues (EBI)

This criterion includes:

1. recognising relevant past and present scientific and social issues
2. explaining the explicit and implicit meanings of information selected from a variety of sources
3. evaluating and assessing the reliability, relevance and bias of the sources or methods of the collection of information
4. justifying decisions and developing future scenarios based on the interpretation and analysis of current information.

Special consideration

Under certain circumstances, special arrangements or consideration may be available to candidates for the Senior External Examination. The special consideration provisions are detailed in the annual Handbook for the Senior External Examination, available on the QSA website at www.qsa.qld.edu.au/testing/extern-exams/handbook.html.

Missing an examination for any reason cannot be the basis for an application for special consideration.

8.3 Awarding levels of achievement

The chief examiner will award each candidate who sits the examination a level of achievement from one of the five categories:

- Very High Achievement (VHA)
- High Achievement (HA)
- Sound Achievement (SA)
- Limited Achievement (LA)
- Very Limited Achievement (VLA).

The process of arriving at a judgment about a candidate's responses to examination questions is essentially a process of matching the candidate's responses against the syllabus standards associated with exit criteria. A level of achievement that best describes the pattern of performance in each criterion across the examination as a whole is then awarded.

Information about how scripts are assessed is provided in the annual Handbook for the Senior External Examination, available on the QSA website www.qsa.qld.edu.au/testing/extern-exams/.

The level of achievement will be based on the exit standard for each of the three criteria *Understanding biology*, *Investigating biology*, and *Evaluating biological issues*. The criteria are derived from the general objectives and are described in section 3. The standards associated with the three exit criteria are described in Table 6.

When standards have been determined in each of the three criteria Table 5 is used to determine the exit level of achievement, where *A* represents the highest standard and *E* the lowest.

Table 5

VHA	The candidate must achieve a Standard *A* in any two exit criteria and no less than a Standard *B* in the remaining criterion
HA	The candidate must achieve a Standard *B* in any two exit criteria and no less than a Standard *C* in the remaining criterion
SA	The candidate must achieve a Standard *C* in any two exit criteria and no less than a Standard *D* in the remaining criterion
LA	The candidate must achieve a Standard *D* in any two exit criteria
VLA	The candidate must achieve a Standard E in at least two criteria

8.4 Table 6 Standards associated with exit levels of achievement

	A	B	C	D	E
Criterion: *Understanding biology*	The candidate communicates understanding by: • making links between related ideas, concepts, principles and theories to reveal meaningful interrelationships • applying knowledge and understanding to a range of complex and challenging tasks.	The candidate communicates their understanding by: • explaining ideas, concepts, principles and theories and describing interrelationships between them • applying knowledge and understanding to a range of complex tasks.	The candidate communicates understanding by: • defining and describing ideas, concepts, principles and theories, and identifying interrelationships • applying knowledge and understanding to a range of tasks.	The candidate communicates understanding by stating ideas and using terminology relevant to concepts and recalling interrelationships.	The candidate states terminology and ideas relevant to concepts.
Criterion: *Investigating biology*	The candidate communicates investigative processes by: • formulating justified researchable questions • designing an investigation by providing methodology, addressing variables and control, planning replicate treatments and identifying data to be collected • organising data to identify trends and interrelationships • interpreting and critically analysing data with links to theoretical concepts to draw conclusions relating to the question(s) • evaluating the design of the investigation and reflecting on the adequacy of the data collected and proposing refinements.	The candidate communicates investigative processes by: • formulating researchable questions • designing an investigation by providing methodology, addressing obvious variables and control and planning replicate treatments • organising data • interpreting data and drawing conclusions relating to the question(s) • evaluating the design of the investigation and the adequacy of the data collected.	The candidate communicates investigative processes by: • identifying researchable questions • designing an investigation by providing incomplete methodology with few variables and attempts to include a control • organising data • using data to draw conclusions.	The candidate communicates investigative processes by: • using data to answer questions. • designing an investigation which provides incomplete methodology and mentions variables • attempting to organise data.	The candidate communicates investigative processes by providing incomplete methodology, and transcribes data.
Criterion: *Evaluating biological issues*	The candidate communicates by: • critically analysing and evaluating information and data from a variety of sources to determine validity, reliability and bias • integrating the information and data to make justified and responsible decisions • comparing alternatives and predictions relevant in past, present and future biological contexts.	The candidate communicates by: • analysing and evaluating information and data from a variety of sources to determine validity, reliability and bias • integrating the information and data to make logical decisions • recognising alternatives and predictions that are relevant in a range of past and present biological contexts.	The candidate communicates by: • analysing information and data from a variety of sources to determine validity and bias • selecting relevant information and data to make plausible decisions and predictions • recognising concepts that form the basis of present-day biological issues in a range of biological contexts.	The candidate communicates by: • making statements related to source material • making unsupported decisions • recognising that a given issue has biological implications.	The candidate communicates by restating supplied information.

9. Resources

The selection of resource material to support study in Biology will be governed to some extent by local factors. It is unlikely that there is a single student or teacher resource which can be universally applied to all programs.

QSA website

The QSA website provides essential resources for all candidates for the Senior External Examination. The website address is www.qsa.qld.edu.au/testing/extern-exams/index.html or go to www.qsa.qld.edu.au > Testing > Senior External Examination.

The following information (current at time of printing) is available:

Senior External Examination Handbook:

- the handbook gives information about
  - how to nominate to sit the examinations
  - teaching centres that provide tuition for the subjects
  - examination timetable
  - important dates relating to the Senior External Examination.

Subject resources

The syllabus and examination papers for the previous three years are available.

Notices to candidates

Information is provided by chief examiners to help candidates prepare for the examination.

Notices to teaching centres

Information is provided by chief examiners to help tutors and candidates prepare for the examination.

Community resources

The material and personnel resources of the local community can help the study of biology. Many aspects of the Biology syllabus could be directly related to local environments. Government departments or agencies are a source of personnel who may provide valuable assistance or advice. The Queensland Museum provides another valuable storehouse of biological materials and expert knowledge. Links with community groups and organisations not only provide relevant and up-to-date resources for candidates.

There may be protocols that must be observed when working with Aboriginal and Torres Strait Islander organisations and community groups, for example meeting with the elders before an activity is conducted. One such set of protocols may be found in the Aboriginal and Torres Strait Islander Studies senior syllabus.

Electronic media

The ABC television series *Catalyst* usually contains items of value. Documentaries produced by the National Geographic Society and similar bodies are telecast frequently and copies of these programs are available, for educational use, at a reasonable cost.

The Science Show and *Ockham's Razor* are regular radio series (on ABC Radio National) pitched at a level appropriate to candidates.

Learning technology

Several computer programs are suitable for use in studying Biology. Such programs include tutorial software, databases of information and simulations of processes and events. CD-ROMs provide interactive access to information presented in a variety of forms. There are also many internet sites offering a rich source of material on topical issues.

Newspaper reports

Some newspapers carry regular columns and features on the impact of science and technology on Australian industry and society. Local papers can also be a source of useful data. The compilation of news files on particular topics can broaden candidates' knowledge. Such news files can also provide a valuable source of material for developing assessment instruments.

Periodicals

Many useful teaching strategies are reported in the *Australian Science Teachers' Journal* as well as the respective state science teachers' journals such as *The Queensland Science Teacher*. These journals often contain details and information about free materials, teaching kits and some worthwhile commercial packages. Useful topics may also be found in science research journals and discipline-specific journals. Lists of these are contained in listings of periodicals held in most libraries.

Commonwealth Science and Industrial Research Organisation (CSIRO) publications contain articles of direct relevance to the topics of this syllabus. Other publications from various sources such as the Australian Academy of Science, conservation and environmental groups and scientific organisations may contain recent and useful information.

Popular science periodicals such as *Scientific American* and *New Scientist* provide information on areas of latest research. *Australasian Science* and the CSIRO periodical *Helix* contain relevant articles. School librarians would be able to provide assistance with identifying and locating other useful periodicals.

Science centres

A number of science centres have been set up in capital cities and in mobile format. For example Questacon — the National Science and Technology Centre in Canberra and the Queensland Museum Sciencentre in Brisbane offer information and programs for schools.

Textbooks and other resources

A wide variety of textbooks and resource materials could be used to supplement a course in Biology. Book suppliers can provide detailed information regarding new publications. The following texts are suggested:

Aubusson, P. & Kennedy, E. 2003, *Biology in Context: the Spectrum of Life*, Oxford University Press, Melbourne, Vic.

Kinnear, J., Martin, M. 2004, *Biology Book 1, Preliminary Course*, Jacaranda HSC Science, John Wiley, Milton, Qld, ISBN 0 7016 3424 3.

Kinnear, J. & Martin, M. 2001, *Biology Book 2, HSC Course*, Jacaranda HSC Science, John Wiley, Milton, Qld, ISBN 0 7016 3465 0.

Spenceley, M., Weller, B., Mason, M., Fullerton, K., Tsilemanis, C., Evans, B., Ladiges, P., McKenzie, J. & Batterham, P. 2004, *Biology: A Contextual Approach*, Heinemann, Melbourne, ISBN 1 74081 351 0

Mason, M., Weller, B., Tsiliemanis, C., Fullerton, K., Coffey, R. & Spenceley, M. 2004, *Biology: A Contextual Approach, Student Activity Manual*, Heinemann, Melbourne, ISBN 1 74081 354 5.

Snyder, W. Kennedy, E. Aubusson, P. *Biology – the Spectrum of Life*, 1990, Oxford University Press, Melbourne, ISBN 0 19 553067 5.

Websites

A plethora of interactive and static websites exist that can be used to enhance study in biology. Here are a few:

Schoolscience (a UK site with free on-line resources showing how to apply the science that students learn at school).
www.schoolscience.co.uk/

Australian National Botanic Gardens and Australian National Herbarium (information to promote Australia's flora — school education programs, botanical databases, biodiversity, etc.). Department of the Environment and Heritage,

www.anbg.gov.au/

Birds Australia (information about Australian birds, watching birds, studying birds, endangered species, etc.).
www.birdsaustralia.com.au

Science.gov.au (Australian Government science portal that has a section on Biological Sciences and Biotechnology).
www.science.gov.au

How Stuff Works (easy-to-read articles, and links to a huge number of subjects, including science).
http://science.howstuffworks.com/