An Roinn Oideachais
Department of Education

Curriculum Specification for Leaving Certificate Biology

For introduction to schools in September 2025.

Prepared by the National Council for Curriculum and Assessment (NCCA)

Contents

Senior Cycle

Senior cycle aims to educate the whole person and contribute to human flourishing. Students' experiences throughout senior cycle enrich their intellectual, social and personal development and their overall health and wellbeing. Senior cycle has 8 guiding principles.

Senior Cycle Guiding Principles
Wellbeing and relationships
Inclusive education and diversity
Challenge, engagement and creativity
Learning to learn, learning for life
Choice and flexibility
Continuity and transitions
Participation and citizenship
Learning environments and partnerships

These principles are a touchstone for schools and other educational settings, as they design their senior cycle. Senior cycle consists of an optional Transition Year, followed by a two-year course of subjects and modules. Building on junior cycle, learning happens in schools, communities, educational settings, and other sites, where students' increasing independence is recognised. Relationships with teachers are established on a more mature footing and students take more responsibility for their learning.

Senior cycle provides a curriculum which challenges students to aim for the highest level of educational achievement, commensurate with their individual aptitudes and abilities. During senior cycle, students have opportunities to grapple with social, environmental, economic, and technological challenges and to deepen their understanding of human rights, social justice, equity, diversity and sustainability. Students are supported to make informed choices as they choose different pathways through senior cycle and every student has opportunities to experience the joy and satisfaction of reaching significant milestones in their education. Senior cycle should establish firm foundations for students to transition to further, adult and higher education, apprenticeships, traineeships and employment, and participate meaningfully in society, the economy and adult life.

The educational experience in senior cycle should be inclusive of every student, respond to their learning strengths and needs, and celebrate, value, and respect diversity. Students vary in their family and cultural backgrounds, languages, age, ethnic status, beliefs, gender, and sexual identity as well as their strengths, needs, interests, aptitudes and prior knowledge, skills, values and dispositions. Every student's identity should be celebrated, respected, and responded to throughout their time in senior cycle.

At a practical level, senior cycle is supported by enhanced professional development; the involvement of teachers, students, parents, school leaders and other stakeholders; resources; research; clear communication; policy coherence; and a shared vision of what senior cycle seeks to achieve for our young people as they prepare to embark on their adult lives. It is brought to life in schools and other educational settings through:

- effective curriculum planning, development, organisation, reflection and evaluation
- teaching and learning approaches that motivate students and enable them to improve
- a school culture that respects students and promotes a love of learning.

Rationale

Leaving Certificate science education provides a means by which students can investigate the natural world to foster an evidence-based understanding of how it works. Students learn that science, as a discipline, is a process that requires logic and creativity to construct scientific knowledge through the sharing of ideas and by developing, refining, and critically analysing these ideas. Students experience science as a personal and collaborative activity that is exciting, challenging and powerful in transforming the world in which we live.

Biology is defined as the scientific study of life. Nature is remarkable and composed of a wide variety of simple and complex systems. Biology attempts to describe and explain these systems with regards to the organisation of life, its structures and processes and the interactions between living things and their environment. In doing so, biology allows us to understand all of life in the past, present and future.

The structures and processes of the cell are shared by all living organisms. Leaving Certificate Biology students develop an understanding of the cell as the unit of life. They are expected to understand the core concepts that govern the living world and apply them to various contexts within biology. They apply scientific knowledge and skills to solve problems and generate solutions. They develop representations of the structures, functions and interactions of living things using the best available evidence as gained through scientific inquiry.

The exploratory nature of Leaving Certificate Biology is experienced by students in both practical and theoretical terms. They have the opportunity to manipulate and use tools, equipment and materials safely, as well as generate and analyse data to answer their questions.

Leaving Certificate Biology students develop a critical awareness of the impact of humankind's decisions on the living world - from our societal impact on species and ecosystems to the personal decisions that influence our health and wellness. They draw on their knowledge and understanding of a number of specified core concepts from different areas of biology to evaluate and use arguments about the place of biology in society. They develop an appreciation of the significance of biology in personal, social, environmental, economic and technological contexts and an awareness of advances in technology, relevant to biology.

Aims

The aim of Leaving Certificate Biology is to provide students with an experience that develops their interest in and enthusiasm for the scientific study of life. In doing so, it aims to build the knowledge, skills, values and dispositions necessary for students to become scientifically literate citizens who are well-prepared for the challenges and opportunities of their future, embracing life-long learning and sustainable living, as citizens in a technologically developing society.

More specifically, Leaving Certificate Biology aims to empower students to:

- build knowledge and understanding of a number of specified core concepts and fundamental principles of biology
- develop the skills, values and dispositions needed to apply this knowledge to explain, analyse, solve problems and predict events in a variety of systems and interactions in the biological world
- demonstrate inquiry and practical skills consistent with the principles and practices of biology
- understand how society and science are interwoven, the everyday relevance of biology and the ethical implications of biology.

Continuity and progression

Leaving Certificate Biology builds on the knowledge, skills, values and dispositions that stem from learners' early childhood education through to the junior cycle curriculum.

Junior Cycle

The learning at the core of junior cycle is described in the Statements of Learning, a number of which apply to scientific concepts, processes and practices, including problem-solving, design and communication skills, and to understanding and valuing the role and contribution of science and technology to society. Student learning in science is unified through the Nature of Science strand, which emphasises the development of a scientific habit of mind.

There is an emphasis on inquiry through which learners develop an understanding and appreciation of structures, processes and fundamental concepts that are essential to all science, as well as the ability to apply scientific principles to their everyday lives. All of the key skills developed across the curriculum during junior cycle support student learning in senior cycle. Many junior cycle subjects and short courses have close links with and support the learning in Junior Cycle Science, particularly mathematics, geography, CSPE, PE, SPHE, home economics and the technologies (T4) subjects.

Junior Cycle Science has close links with Leaving Certificate Biology in helping students to continue to develop their evidence-based understanding of the natural world; to develop their capacity to gather and evaluate evidence; to consolidate and deepen their skills of working scientifically; to make them more self-aware as learners and to become more competent and confident in their ability to use and apply science in their everyday lives. Students build on theses scientific concepts, processes and practices as they progress through the two years of Leaving Certificate Biology.

Beyond senior cycle

Biology builds a solid foundation for students to progress to diverse futures, including participation in society, the worlds of work, further education and training, and higher education, in specialised areas such as science, engineering, technology-related jobs, computer science, education, mathematics, medicine, agriculture, business and finance.

The learning experienced while studying biology can lead to many exciting and rewarding careers in the discipline and also provide a foundation for a diverse range of opportunities in related areas, including biomedical, environmental, agricultural, food, health, sports, forensic sciences and biotechnology.

In addition, biology incorporates a broad range of skills, including systems thinking, observation, classification, creative design, synthesis, and evaluation of information. It teaches a range of generically useful skills in areas such as communication, time management, organisation, and teamwork. These skills are relevant to all further study, and indeed all learning beyond formal education.

Biology has an immediate relevance to our daily lives. Students develop an appreciation of the social and cultural perspectives of biology and of the impact of science and technology on people and on the environment. Biology lies at the heart of issues which challenge our confidence as a species now and in the future, including global disease prevention and control, sensible management of the environment and effective control of human populations. These challenges will require not only innovative science solutions, but also social, political and economic ones that are informed by knowledge of the science that underpins them.

By studying biology, students appreciate the role of community and society in the complex ecology of the planet and of its sustainable development. They consider aspects of health and illness in terms of promoting health and reducing the risk of disease. They appreciate that the spread of disinformation is threatening democracies world-wide. Rationality and scepticism are important principles embedded in Leaving Certificate Biology. Students learn the importance of reliable sources, peer review, ethics and evidence in logical decision-making and are well poised to address these challenges.

Student learning in senior cycle

Student learning in senior cycle consists of everything students learn **within** all of the subjects and modules they engage with **and** everything students learn which spans and overlaps **across** all of their senior cycle experiences. The overarching goal is for each student to emerge from senior cycle more enriched, more engaged and more competent as a human being than they were when they commenced senior cycle.

For clarity, the learning which spans **across** all of their senior cycle experiences is outlined under the heading 'key competencies'. The learning which occurs **within** a specific subject or module is outlined under the heading 'strands and learning outcomes'. However, it is vital to recognise that key competencies and subject or module learning are developed in an integrated way. By design, key competencies are integrated across the rationale, aims, learning outcomes and assessment sections of specifications. In practice, key competencies are developed by students in schools via the pedagogies teachers use and the environment they develop in their classrooms and within their school.

Subjects can help students to develop their key competencies; and key competencies can enhance and enable deeper subject learning. When this integration occurs, students stand to benefit

- during and throughout their senior cycle
- as they transition to diverse futures in further, adult and higher education, apprenticeships, traineeships and employment, and
- in their adult lives as they establish and sustain relationships with a wide range of people in their lives and participate meaningfully in society.

When teachers and students make links between the teaching methods students are experiencing, the competencies they are developing and the ways in which these competencies can deepen their subject specific learning, students become more aware of the myriad ways in which their experiences across senior cycle are contributing towards their holistic development as human beings.

Key competencies

Key competencies is an umbrella term which refers to the knowledge, skills, values and dispositions students develop in an integrated way during senior cycle.

Figure 1: The components of key competencies and their desired impact

The knowledge which is specific to this subject is outlined below under 'strands of study and learning outcomes'. The epistemic knowledge which spans across subjects and modules is incorporated into the key competencies.

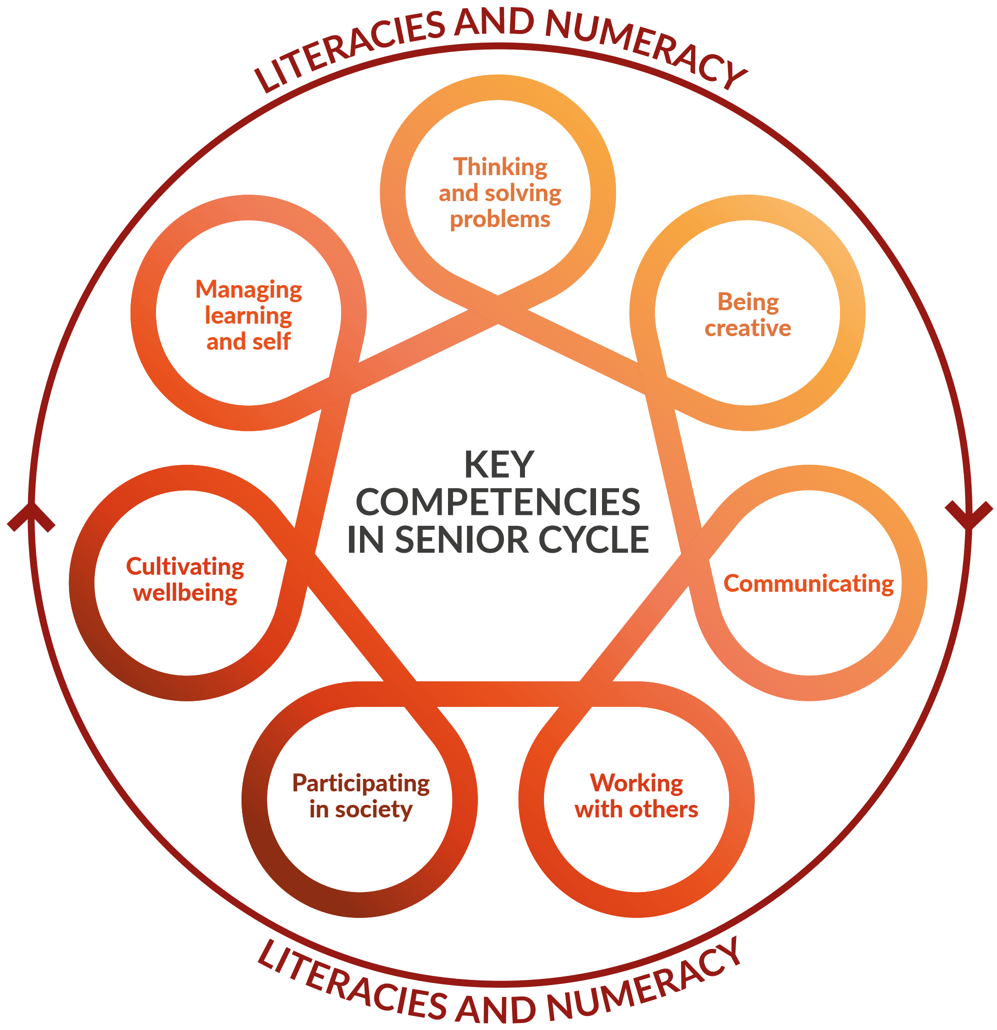

Figure 2: Key Competencies in Senior Cycle, supported by literacies and numeracy

These competencies are linked and can be combined; can improve students' overall learning; can help students and teachers to make meaningful connections between and across different areas of learning; and are important across the curriculum.

The development of students' literacies and numeracy contributes to the development of competencies and vice-versa. Key competencies are supported when students' literacies and numeracy are well developed and they can make good use of various tools, including technologies, to support their learning.

The key competencies come to life through the learning experiences and pedagogies teachers choose and through students' responses to them. Students can and should be helped to develop their key competencies irrespective of their past or present background, circumstances or experiences and should have many opportunities to make their key competencies visible. Further detail in relation to key competencies is available at https://ncca.ie/en/senior-cycle/senior-cycle-redevelopment/student-key-competencies/

These competencies can be developed in Leaving Certificate Biology in a range of ways.

As students become curious about the natural world, they learn to express their curiosities in the form of scientific questions. They seek answers to these questions through the practices of investigation, trying out new approaches in response to situations and **being creative** in their investigate methods. Through the experience of Leaving Certificate Biology, students develop a scientific habit of mind. This involves drawing on a set of established practices, in which **thinking and solving problems** is of great significance. They access, gather and process information from a variety of sources in both familiar and new situations. They do so with an open mind, underpinned by a natural curiosity about how the world works as they ask questions, gather and explore data, observe, and investigate the living and non-living worlds. As critical thinkers, students need to continually examine their lines of argument, the evidence for their claims, and the motivations behind their beliefs.

Communicating scientific concepts and discoveries is an important aspect of the work of a scientist. As Leaving Certificate Biology students prepare scientific communications, they develop an awareness of the need to present ideas in ways that are true to the claims being made but also appropriate to the intended audience. They frame scientific arguments by making claims and using logical reasoning based on evidence, using relevant scientific language and terminology. Through developing their scientific communication skills, students also learn to listen actively, to question evidence and to seek clarity and understanding. Through their classroom experiences, students learn about **working with others**, as they co-operatively learn in pairs, groups and teams. They take on different roles, work together to achieve shared goals, give and respond to feedback from their teachers and peers, and interact safely and responsibly. These behaviours increase students' sense of self-efficacy as they become flexible, adaptable and willing to learn from mistakes. These attributes positively contribute to **managing learning and self** in the biology classroom.

Biology provides an opportunity for students to critique and challenge systems that damage the natural world, and leads to the creation of knowledge for sustainable futures. Through becoming scientists, students are **participating in society**, contributing to a sustainable world in their schools, communities, wider society, and through their own personal behaviours and choices. In their study of biology, students may face challenges and difficulties in their engagement with primary and secondary data. Scientific investigation is not a linear process and sometimes unexpected results and errors may occur. As students work through challenges, they build their individual and group resilience as investigators, assessing and responding to risks and errors in healthy ways. This helps in **cultivating wellbeing** in biology classrooms, as students learn to support and help each other. They further cultivate wellbeing through applying their knowledge of biology to live healthy personal lives, and in their care for the living world through their career pursuits and everyday lifestyle choices.

Literacies and numeracy support the development of key competencies in the Leaving Certificate Biology classroom, and vice-versa. This is particularly relevant where students gather and interpret primary data, using a variety of analogue and digital means. Through their critical evaluation of secondary data from reliable sources, students' scientific literacy is further enhanced. As they develop data-driven representations to explain scientific phenomena, students draw on and develop their various competencies in subject specific and cross-disciplinary ways.

Strands of study and learning outcomes

This Leaving Certificate Biology specification is designed for a minimum of 180 hours of class contact time. It sets out the learning in strands and through the identification of cross-cutting themes. There are four strands: a unifying strand, Nature of Science, and three contextual strands, Organisation of Life, Structures and Processes of Life, and Interactions of Life.

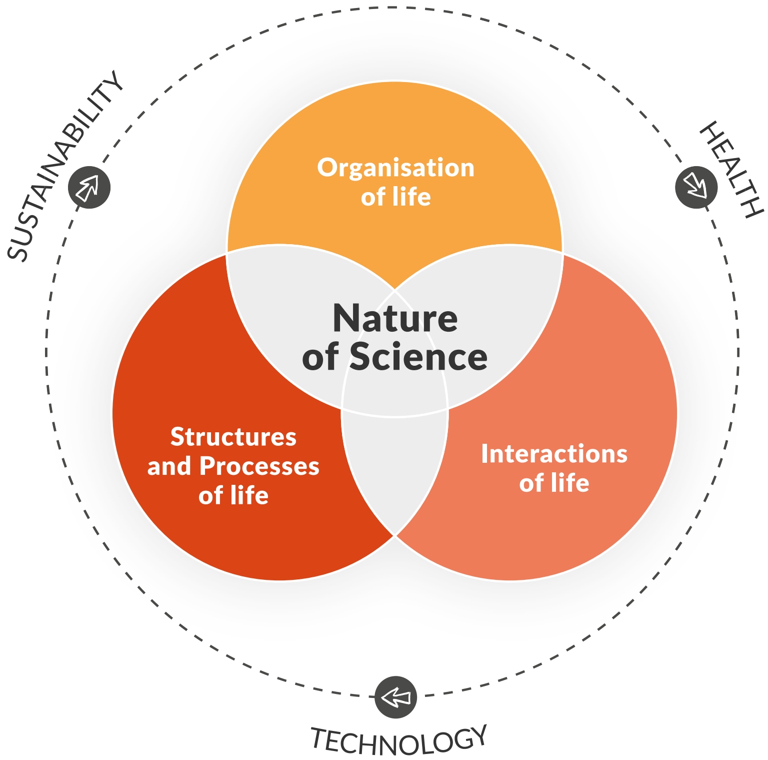

Figure 3: Overview of Leaving Certificate Biology

The unifying strand, Nature of Science, reflects continuity and progression from Junior Cycle Science and involves students applying the principles and practices of science to their biology learning in the three contextual strands. The learning outcomes in the unifying strand identify the knowledge, skills, values and dispositions related to scientific practices which are essential to students' learning *about* science throughout the course, underpinning the activities and content in the other strands.

The learning outcomes in the other three contextual strands—Organisation of Life, Structures and Processes of Life, and Interactions of Life—identify the knowledge *of* biology which includes its core concepts, models and theories that explain and predict biological phenomena.

The specification identifies three crosscutting themes – *Health*, *Sustainability* and *Technology*. These themes, illustrated as surrounding the contextual strands, permeate and provide contexts for the study of these strands. They act as lenses through which students explore the application of knowledge *from* biology. Through these lenses, students engage with contemporary issues in biology as they pose questions and integrate and apply their learning from across the specification.

The specification is presented in the form of learning outcomes. The outcomes are statements of what the student should be able to do having completed the unit of study. The sequence in which the strands and learning outcomes are presented does not imply any particular order of teaching and/or learning, although it should follow a logical and coherent approach. Appropriate links should be made between the strands.

Learning outcomes should be achievable relative to each student's individual aptitudes and abilities. Learning outcomes promote teaching and learning processes that develop students' knowledge, skills, values and dispositions incrementally, enabling them to apply their key competencies to different situations as they progress. Students studying at both Ordinary level and Higher level will critically engage with biology, but the context, information and results associated with that analysis are presented at different levels.

Ordinary level	Higher level
• Only the learning outcomes that are presented in normal type.	• All learning outcomes including those **in bold type**.
• Students engage with a broad range of knowledge, mainly concrete in nature, but with some elements of abstraction or theory.	• Students engage with a broad range of knowledge, including theoretical concepts and abstract thinking with significant depth in some areas.
• Students demonstrate and use a moderate range of cognitive skills and tools to us information, plan and develop investigative strategies and select from a range of procedures and apply known solutions to a variety of problems. They identify and apply skills and knowledge in both familiar and unfamiliar contexts.	• Students demonstrate and use a broad range of specialised skills to evaluate, and use information, to plan and develop investigative strategies, and to determine solutions to varied problems. They identify and apply skills and knowledge in a wide variety of both familiar and unfamiliar contexts.
• Students develop scientific literacy skills and use evidence and data to communicate findings and draw conclusions to questions posed by themselves and others.	• Students develop, demonstrate and use scientific literacy skills and use appropriate evidence and data to effectively communicate findings and draw valid conclusions to questions posed by themselves and others.

Table 1: Design of learning outcomes for Ordinary and Higher level

An overview of each strand is provided below, followed by a table. The right-hand column contains learning outcomes which describe the knowledge, skills, values and dispositions students should be able to demonstrate after a period of learning. The left-hand column outlines specific areas that students learn about. Taken together, these provide clarity and coherence with the other sections of the specification. Appendix 1 sets out a glossary of action verbs used in the Learning Outcomes.

Unifying Strand: Nature of Science

This strand builds on the unifying strand from Junior Cycle Science and continues to bring to life the practices and norms underpinning the facts, concepts, laws, and theories of science. Building on existing knowledge, students develop an appreciation of science as a process; a way of knowing and doing and an understanding that the discipline of science includes understanding the nature of scientific knowledge as well as how this knowledge is generated, established and communicated. In senior cycle it is expected that students will be able to meet these learning outcomes with a greater degree of independence.

As they learn to work like scientists, they develop a habit of mind that sees them rely on a set of established procedures and practices associated with scientific inquiry to gather evidence, generate models[1] and test their ideas on how the natural world works. It becomes apparent that the process of science is often complex and iterative, following many different paths. Students will learn to obtain and evaluate primary data (i.e., collected by themselves) and secondary data (data collected by somebody else).

Students develop an understanding that whilst science is powerful, generating knowledge that forms the basis for many advances and innovations in society, it has limitations and that the application of scientific knowledge to problem-solving can be influenced by considerations such as economic, social, sustainability and ethical factors.

Unifying Strand Learning Outcomes

Students learn about	Students should be able to
U1 Scientific knowledge • the nature of scientific knowledge • science as a global enterprise that relies on clear communication, international conventions, peer review and reproducibility • recognising bias	**1.** appreciate how scientists work and how scientific ideas are modified over time **2.** conduct research relevant to a scientific issue, evaluate different sources of information including secondary data, understanding that a source may lack detail or show bias

[1] Representations of ideas, structures, processes, or systems through a variety of means such as words, diagrams, equations, physical models or simulations

Students learn about	Students should be able to
U2 Investigating in Science	
• questioning and predicting	**1.** recognise questions that are appropriate for scientific investigation **2.** pose testable hypotheses developed using scientific theories and explanations, and evaluate and compare strategies for investigating hypotheses

• objectivity
  • identifying potential sources of random and systematic error
  • evaluating data in terms of repeatability and reproducibility
	3. design, plan and conduct investigations; explain how reliability, accuracy, precision, error, fairness, safety, integrity, and the selection of suitable equipment have been considered
	4. produce and select data (qualitatively/quantitatively), critically analyse data to identify patterns and relationships, identify anomalous observations, draw and justify conclusions
	5. review and reflect on the skills and thinking used in carrying out investigations, and apply their learning and skills to solving problems in unfamiliar contexts

• communicating results to a range of audiences	**6.** organise and communicate their research and investigative findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and representations
U3 Science in society	
• evaluating evidence for relevance, accuracy, bias	**1.** evaluate media-based arguments concerning science and technology
• relating science and scientists to society by considering economic, social, sustainability and ethical factors	**2.** research and present information on the contribution that scientists make to scientific discovery and invention, and evaluate its impact on society
U4 Biological reasoning	
• generating and using models • the evolving nature of models	**1.** appreciate that models • are simplified representations of complex systems or phenomena with underlying assumptions • can be modified as more data becomes available from the system/phenomenon • can predict the behaviour of a system/phenomenon

Students learn about	Students should be able to
• means by which to explain biological phenomena: • systems • interdependence, unity and diversity of life • form fits function • transfer of information, matter, and energy, etc.	**2.** explain biological phenomena using appropriate means

Strand 1: Organisation of Life

In this strand, students gain knowledge and understanding of a number of core concepts to explain the organisation and diversity of life.

Students learn about characteristics of living things and how they relate to what constitutes life. Referring to viruses, they engage with evidence that argues the case for living and non-living.

Through the study of kingdoms, students learn how to classify living things. They appreciate that classification systems have, and continue to, change based on emerging evidence and new technologies that help us to understand evolutionary connections and common ancestry in greater detail.

Students are introduced to the cellular basis for life and the complexity of life, based on cells. They learn about the structures and functions of cell organelles through the analysis of primary and secondary data. They appreciate that all life is organised into cells and that the structures and processes of cells are shared by all organisms. In Strand 2 students explore how these cellular components work together to carry out functions and how cellular processes enable organisms to maintain homeostasis.

Students appreciate the structure and role of various biomolecules in nutrition, structure, control of metabolic pathways and transfer of information. In Strands 2 and 3 they explore processes through which these biomolecules are transferred through the living world.

Students learn how genetic information is organised and transferred. They use Mendel's Laws and its associated concepts as a mechanism for explaining genetic inheritance. They develop and use models to explain, analyse and predict genetic inheritance in various contexts.

As students learn about the theory of evolution by means of natural selection, they appreciate it remains the best explanation for the progression and diversity of life. They consider evidence from a variety of sources to support this robust theory.

Strand 1 Learning Outcomes

Students learn about	Students should be able to
1.1. Characteristics of life	
• characteristics of living things • organisation • response • respiration • nutrition • excretion • reproduction • growth • metabolism • homeostasis • heredity • cellular basis	**1.** outline the characteristics of living things
• structure and functions of a virus including constituents (DNA or RNA, protein coat),	**2.** discuss the difficulty of defining viruses, their economic and medical importance

Students learn about	Students should be able to
• domains of life including archaea, bacteria, eukaryota,	**3.** outline the domains of life system based on genetic characteristics
• classification systems as evolving and important systems in biology • taxonomic classification of life including the kingdoms – bacteria, archaea, protista, fungi, plantae, and animalia • prokaryotic and eukaryotic as a means of classifying living things • phylogeny – classification based on evolutionary development, with reference to genus and species • emerging evidence to enhance systems of classification	**4.** use classification principles to identify and classify living things in known and unknown contexts; outline the importance of classification systems in biology
1.2. Chemicals of life – biomolecules	

• biomolecules in living cells involved in anabolism, catabolism, energy transfer, formation of structural units, rearrangement into new molecules
• structures
  ◦ carbohydrates ($C_x(H_2O)_y$) – mono, di, polysaccharides
  ◦ lipids (triglyceride unit and different combinations in fats, oils and phospholipids)
  ◦ proteins – peptides and polypeptides, folded into shapes, made up of amino acids, containing the elements carbon, hydrogen, oxygen, nitrogen and sometimes sulphur, phosphorous or other elements
  ◦ nucleic acid (nucleotides)
• metabolic roles
  ◦ hormones as regulators
  ◦ protein roles including enzymes, hormones, membrane interactions, immunity
  ◦ proteins necessary for molecular mechanisms including channel proteins, transporters, structural proteins and receptors
  ◦ carbohydrates and lipids in catabolic, anabolic, respiratory, photosynthetic functions
	1. outline the structures and metabolic roles of carbohydrate, lipid and protein, and identify nutritional sources of each

Students learn about	Students should be able to
• minerals which are not necessarily integrated into biomolecules are needed in small amounts by organisms for pH balance, regulation of enzyme systems, nerve impulse transfer and muscle contraction	**2.** recognise the roles of minerals in biological processes
• sources of nutritional molecules (proteins, lipids, carbohydrates, water-soluble and fat-soluble vitamins, minerals) • the biological significance of vitamin solubility	**3.** outline the role of vitamins in biological processes, including the role of one water soluble and one fat soluble vitamin in humans, and their associated deficiency disease
• roles of water including medium for transport and chemical reactions, regulation of temperature, ph, osmoregulation	**4.** outline the main roles of water in living organisms
• testing for the presence of nutrients in food including carbohydrates, protein, and lipids	**5.** investigate qualitatively the presence of nutrients in a range of food samples, use primary data to support conclusions **6.** investigate quantitatively the level of reducing sugars in a range of food samples, use primary data to support conclusions
• nucleic acids: ◦ sugar molecule (ribose in RNA, deoxyribose in DNA), phosphate and nitrogenous base ◦ DNA – double stranded helix with adenine/thymine, cytosine/guanine base pairs. ◦ RNA basic structure with reference to uracil	**7.** describe the basic structure and function of a DNA and RNA nucleotide
• transfer molecules in cell activities, including ATP in transferring energy and **NAD^+ and $NADP^+$ in electron transfer (different roles in photosynthesis and respiration)**	**8.** outline the role of ATP, **NAD^+ and $NADP^+$** in metabolic pathways
• **DNA containing a genetic code, which is read by cellular machinery to produce proteins. Reference to codons and anticodons**	**9.** relate genes, proteins and traits in organisms; **outline the concept of the genetic code**
1.3. Unit of life – cells	
• organisation of life in increasing complexity from individual cells to organism level	**1.** describe the complexity of multicellular organisms
• images of cells and their parts from a light microscope and electron microscope	**2.** compare the structure of prokaryotic and eukaryotic cells

Students learn about	Students should be able to

• microscopy – existing and emerging fields including optical and electron microscopy, use and function of a light microscope
• preparing and mounting a slide for viewing in a light microscope
• structures and organelles of animal and plant cells:
  ◦ cell wall
  ◦ cell membrane
  ◦ cytoplasm
  ◦ vacuole
  ◦ mitochondrion
  ◦ chloroplast
  ◦ nucleus
  ◦ nuclear pore
  ◦ ribosome
  ◦ chromosome
  ◦ **endoplasmic reticulum**
  ◦ **Golgi apparatus**
	3. investigate, using primary data gathered with a light microscope and secondary data gathered from scanning electron microscope imagery, the structures and organelles of animal and plant cells and relate them to their functions

1.4. Information of life – genetic inheritance	

• chromosome structure including protein (**histones**) and DNA, **chromatids**, **centromere**, reference to chromatin, coding and non-coding DNA
• key concepts related to transfer of information
  ◦ species
  ◦ gamete
  ◦ sexual reproduction
  ◦ fertilisation
  ◦ heredity
  ◦ chromosome
  ◦ allele
  ◦ gene expression
  ◦ **epigenetic expression**
  ◦ dominance
  ◦ recessive
  ◦ genotype, phenotype
  ◦ **incomplete dominance**
  ◦ **linkage, sex-linkage**
	1. describe the structure of a chromosome and the role of a gene

• nuclear inheritance via transmission of DNA **vs non-nuclear inheritance in mitochondrial and chloroplast DNA**	**2.** explain what is meant by nuclear inheritance; **compare to non-nuclear inheritance**
• genetic mechanisms – inheritance through passing on of DNA • the concept of epigenetics/epigenetic expression – how behaviours and environment influence gene expression, some are reversible	**3.** compare genetic and epigenetic mechanisms; **research one example of epigenetic inheritance in nature**

Students learn about	Students should be able to
• monohybrid and **dihybrid crosses**	**4.** model inheritance to the first generation of a single unlinked trait in crosses involving homozygous and heterozygous parents **5. model a cross involving incomplete dominance**

• **Mendel's Laws of segregation and independent assortment**
  • **linkage**
  • **crossing over not required**
	6. illustrate and state Mendel's Laws of Segregation and Independent Assortment
	7. model inheritance to the second generation of two unlinked traits in crosses involving homozygous and heterozygous parents
	8. explain how linkage affects Mendel's Law of Independent Assortment (knowledge of crossing over not required)

• sex-linked traits including colour blindness and haemophilia	**9.** model sex determination by X and Y chromosomes in humans **10.** model the inheritance of sex-linked traits from known examples

• benefits and limitations of Mendelian genetics:
  • predictive power of Mendelian genetics
  • Mendel's Laws not applying for complex traits involving multiple gene interactions or environmental factors
	11. identify benefits and limitations of Mendelian genetics to our understanding of heredity in the modern world

1.5. Origins of life – evolution • evolutionary theory as a mechanism for explaining and predicting common origins and future directions for highly specialised organisms	**1.** explain the variations that come from sexual reproduction and mutations
• natural vs artificial selection; mutations (gene and chromosome)	**2.** discuss the rationale for, and basis of, the theory of evolution by natural selection

Students learn about	Students should be able to

• sources of evidence such as:
  ◦ embryology
  ◦ fossil records
  ◦ phylogeny
  ◦ comparative anatomy
  ◦ antibiotic resistance
  ◦ speciation, etc.
• the concept of a theory
• how the theory of evolution is one of the most widely accepted and tested theories in science
• how the theory of evolution presents the best available explanation for how life on Earth has and continues to evolve
	3. consider evidence for evolution by natural selection; discuss the importance of the theory of evolution in understanding biology

Strand 2: Structures and Processes of Life

In this strand students learn how the unique and diverse structures within living things allow life to function through a number of processes taking place within cells, organs and systems. As students investigate the structures and processes of living things, they appreciate that all life depends on the transfer of energy and matter through these processes. They recognise that all organisms store information and rely on proteins in their cells, including enzymes, to carry out specific functions. They learn about the cellular processes of photosynthesis, respiration, cell division and protein synthesis as fundamental for transference of energy, matter and information through the living world.

In Strand 1, students learn about biomolecules involved in transfer, including ATP, NAD+ and NADP+. In Strand 2, they consider these molecules in the context of cellular processes as they investigate photosynthesis and respiration. They learn how cells, organs and systems interact to facilitate the transport and transfer of biomolecules within organisms, as well as their exchange with the external environment. In Strand 3, students explore the transfer of biomolecules between living things and their recycling through habitats, ecosystems and the biosphere.

In Strand 1, students apply their knowledge of genetic laws to model genetic inheritance through generations. In Strand 2, they consider the structures and function of cell division and protein synthesis to further understand how transfer of information occurs. They explore the mechanisms of reproduction to allow for the transfer of information and continuity of life. They learn about the centrality of the genetic code to our understanding of life and its continuation, including our understanding of health and disease. In Strand 3, they consider modern advancements in the manipulation of genetic code, as well as the ethical and societal implications of these advancements.

Students appreciate the importance of homeostasis as a fundamental characteristic of living things. As they explore how different organs and systems function and interact, they appreciate how the structures and processes within organisms are designed to function both individually and collectively to facilitate the organism responding to internal and external change.

Strand 2 Learning Outcomes

Students learn about	Students should be able to
2.1. Enzymes	
• enzymes as selective catalysts controlling biochemical reactions; the importance of enzymes in metabolism	**1.** explain how enzymes function to facilitate the catalysis of biochemical reactions
• **importance of 3D structure for enzyme specificity and activity**	**2. illustrate enzyme activity using the Induced Fit model.**

Students learn about	Students should be able to
• rate of enzyme activity (conversion of substrate into product per unit time) influenced by ◦ substrate concentration ◦ enzyme concentration ◦ environmental pH ◦ temperature ◦ subject to denaturation	**3.** investigate factors affecting the rate of enzyme-catalysed reactions, use primary and secondary data to support conclusions
• use of enzymes in a wide range of industries including ◦ food and beverages ◦ biofuels ◦ medicine ◦ pharmaceuticals	**4.** research the use of enzymes in industries; recognise the central role of enzymes in industrial applications, including immobilised enzymes
2.2. Cellular processes – photosynthesis and respiration	
• cellular processes: ◦ photosynthesis and respiration as anabolic and catabolic reactions respectively ◦ the role of photosynthesis as a carbon sink, resulting in production of glucose in plants and leading to production of sucrose and complex carbohydrates ◦ the role of respiration in carbon release and energy transfer (as ATP) for cellular activities ◦ sources of reactants and products of both processes ◦ representation of the overall sequence of photosynthesis and respiration, including their cellular locations and balanced equations	**1.** outline the processes of anaerobic respiration, aerobic respiration and photosynthesis
• factors affecting rate of photosynthesis including ◦ temperature ◦ light intensity ◦ CO_2 levels	**2.** investigate factors affecting the rate of photosynthesis, use primary and secondary data to support conclusions

Students learn about	Students should be able to
• conditions necessary for fermentation to occur: ◦ presence of sugars and microorganisms (yeast or bacteria) ◦ anaerobic environment ◦ suitable temperature	**3.** investigate the conditions necessary for fermentation, use primary and secondary data to support conclusions
• **first and second stage process of respiration:** ◦ **first-stage process: glycolysis – the conversion of a six-carbon carbohydrate to pyruvate with the generation of ATP.** ◦ **fermentation products, depending on organism and conditions, can be either ethanol or lactic acid.** ◦ **second-stage process: pyruvate is broken down to produce AcetylCoA and one molecule of carbon dioxide.** ◦ **AcetylCoA enters a series called citric acid cycle resulting in the production of CO_2 and H_2O. Electrons from the cycle transferred through an electron transport chain, energy from this transfer is used in the production of ATP molecules which can be used for other biochemical reactions within the cells** • **light dependent and light independent reactions of photosynthesis:** ◦ **light dependent reactions (non-cyclic pathway) involves the absorption of a photon of light, passed from one pigment molecule to others in the chloroplast until it reaches a reaction centre in a chlorophyll molecule. Photolysis of water due to attraction from positively charged chlorophyll molecule results in production of oxygen and electron transfer results in the production of ATP and NADPH (from $NADP^+$)** ◦ **light dependent reactions (cyclic pathway) - some electrons return to chlorophyll and transfer surplus energy to the formation of ATP in an alternative pathway** ◦ **NADPH and ATP enter the light independent reactions – protons and electrons are transferred from NADPH to CO_2 in the production of $C_6H_{12}O_6$. Energy to achieve this conversion comes from ATP. ADP and $NADP^+$ return to the light dependent reactions and can be re-used.**	**4. model the two-stage processes of photosynthesis and respiration; make particular reference to the role of transfer molecules**

Students learn about	Students should be able to
• **cellular structures facilitating photosynthesis and respiration:** ◦ **electron transport chains involving a number of protein complexes and mobile electron carriers embedded in the mitochondrial membrane (respiration) and thylakoid membrane (photosynthesis)** ◦ **transfer of electrons to protein complexes causes a charge difference which attracts protons to the complex, given by donor molecules** ◦ **these protons pass through the complex outside the mitochondrial inner membrane, creating a high concentration of protons outside the membrane.** ◦ **protons flow back down the gradient, across the inner membrane, through the enzyme ATP synthase, which harnesses the flow of protons to make ATP.**	**5. recognise the significance of the internal structures of mitochondria and chloroplasts in facilitating the processes of photosynthesis and respiration**
2.3. Information of life - cell division, protein synthesis	
• cell cycle involving growth, DNA synthesis and division summarised in the cell cycle involving ◦ **Interphase – cell growth and DNA replication** ◦ **Nuclear division – prophase, metaphase, anaphase and telophase** ◦ **Cytokinesis** • the concepts of haploid and diploid	1. outline the cell cycle
• cell division as a transmission of genetic code to the next generation: ◦ mitosis – genetic information remains the same ◦ meiosis – variation of the genetic information	2. compare the roles of mitosis and meiosis in transmitting genetic information in unicellular and multicellular organisms
• process of DNA replication, facilitated by enzymes and involves separating the double strand of DNA into two single strands, each of which serve as the template for the synthesis of a complementary strand of DNA	3. explain the role of DNA replication and mitosis in the cell cycle

Students learn about	Students should be able to

• **how genetic information is transcribed from DNA to mRNA, which is then transferred to ribosomes where it is translated into specific proteins**
• **roles of**
  ◦ **DNA**
  ◦ **mRNA**
  ◦ **tRNA**
  ◦ **rRNA**
  ◦ **polymerase**
  ◦ **ribosomes**
in transcribing and translating genetic code into amino acids, arranged in correct sequence to synthesise the protein which folds into functional shape
	4. model how DNA is replicated and the flow of information through mRNA to protein
	5. model the processes of transcription and translation; relate the structure of tRNA to the codon nature of the genetic code

• **point mutation occurring due to incorrect base pairing during replication resulting in a change in nucleotide sequence; chromosomal mutations as a change in genes in a chromosome or chromosomes including by deletion, duplication, insertion, substitutions**	**6. model how point and chromosomal mutations occur, making reference to known examples of both**

• characteristics and growth of cancer cells including abnormal regulation of mitotic division and rate
• emerging evidence in cancer research offering insights for prevention and/or treatment, including
  ◦ early detection
  ◦ treatments
  ◦ vaccination
  ◦ lifestyle changes
	7. outline how uncontrolled cell proliferation can lead to development of cancers
	8. examine the role of infectious agents, environmental factors and/or genetic susceptibility in the development of different cancers in an organism; evaluate factors that impact the development of cancers

2.4. Response
• structures and systems for response including
  ◦ hormonal system
  ◦ nervous system
  ◦ musculoskeletal system
  ◦ immune system
  ◦ various anatomical and chemical adaptations in plants
	1. outline the structures and systems for response in humans and plants

Students learn about

The musculoskeletal system

- component parts of the axial skeleton:
  - skull
  - vertebrae
  - ribs
  - sternum
- position and function of discs in relation to vertebrae.
- component parts of the appendicular skeleton:
  - pectoral girdle – clavicle, scapula
  - pelvic girdle (names of bones in pelvic girdle not required)
- component parts of attached limbs of the appendicular skeleton:
  - femur
  - patella
  - tibia
  - fibula
  - humerus
  - radius
  - ulna.

The nervous system

- central nervous system – brain and spinal cord.
- peripheral nervous system – location of nerve fibres and cell bodies.
- role, structure and mechanisms of the reflex action (cranial nerves, sympathetic and parasympathetic systems are not required)
- homeostasis as a model of stimulus-response in resistance to external or internal change, appropriate responses occur via negative feedback, nervous and hormonal pathways link a control centre with receptors and effectors in vertebrates

Students should be able to

2. relate the structures of the component parts of the axial and appendicular skeleton to their functions
3. model the function of an antagonistic muscle pair; relate the functions of cartilage, ligament and tendons in synovial joints
4. relate the structure of the parts of the central nervous system and the peripheral nervous system to their functions
5. compare nervous and hormonal coordination

Students learn about	Students should be able to
• neuron parts: • cell body • dendrites • axon • myelin sheath • Schwann cell • neurotransmitter vesicles	**6.** relate the structures of a motor and sensory neuron to their functions
• neurotransmission: • transmission of nerve impulse via neurons (sensory, motor, interneurons) • role of neurotransmitters at a synapse in conduction of nerve impulses, involving movement of ions (detailed knowledge of electrochemistry not required)	**7.** explain the role of neurotransmitters at a synapse
• **conduction of nerve impulses:** • **neurotransmitters activated by ions, released into cleft for short time, transmitting the impulse to the next neuron** • **neurotransmitter inactivated by an enzyme after transmission, reabsorbed by the presynaptic neuron to make new neurotransmitter substance** • **disruptions to this mechanism leading to acute and chronic disorders which are treated through drugs that inhibit enzymes that degrade neurotransmitters or inhibit reuptake of neurotransmitters at the synapse, creating an enhanced effect (similar processes for psychoactive drugs and painkillers)**	**8.** **model impulse travel across a synaptic cleft, consider the impacts of disruptions to impulse travel**
• neurotransmission effects mood and behaviour – functions of endorphins and dopamine • lifestyle choices that impact dopamine and endorphin levels including non-medical drug use, exercise, dietary choices	**9.** Discuss the roles of the neurotransmitters dopamine and endorphins in humans, taking into account the influence of lifestyle choices on their levels in the human body

Students learn about	Students should be able to

The endocrine system
• endocrine system including the following glands, their locations and secretions:
  • adrenal (adrenaline)
  • pituitary (**FSH**, **LH**, oxytocin, TSH, **ADH**)
  • thyroid (thyroxine)
  • parathyroid (parathyroid hormone)
  • pancreas (insulin)
  • testes (testosterone)
  • ovaries (oestrogen, progesterone)
	10. identify the location of the major glands in the endocrine system, describe the functions of their associated hormones

• uses of hormonal manipulations • sport • health • agriculture	**11.** recognise the impact of hormonal manipulations on organisms

Immunity
• pathogens including
  • prions • bacteria • protists
  • viruses • fungi • parasitic animals
• innate immune response to the presence of pathogens
• adaptive immune response of vertebrates including antigen antibody response
• **B and T lymphocyte roles in cell-mediated immune response,**
• acquired immunity as acquired by infection, vaccination (active), or donor transfer of lymphocytes (passive) by various means such as antibody booster injections and breastfeeding
	12. distinguish between innate and acquired immunity; outline the strategies applied to prevent and treat microbial diseases

• modes of action and replication • differences between DNA and RNA viruses	**13.** model how viruses replicate within cells

• **different types of white blood cell:**
  • **monocytes**
  • **natural killer cells**
  • **B lymphocytes**
  • **T lymphocytes (helper, killer, suppressor and memory)**
	14. compare the roles of different types of white blood cell in immune response

Students learn about	Students should be able to

• transmission and spread of infectious disease facilitated by local, regional and global movement of organisms.
• Emergence and spread of diseases dependent on interrelated factors including
  ◦ persistence of the pathogen in a host
  ◦ mutations
  ◦ antibiotic or chemical resistance
  ◦ immunity level present in the population
  ◦ mobility in affected populations
  ◦ reproduction number (R_0 value)
	15. explore factors that contribute to the emergence of infectious diseases in plants and animals

• novel viruses in plants and animals and autoimmune diseases • understanding factors leading to increased numbers enables strategies to control the increase	**16.** discuss the importance of a knowledge of emerging diseases in society

2.5. Reproduction
 	
Human reproduction
• structure of the human male reproductive system:
  ◦ penis ◦ testes ◦ vas deferens
  ◦ foreskin ◦ epididymis ◦ seminal vesicle
  ◦ glans ◦ urethra ◦ prostate
  ◦ scrotum
• structure of the female reproductive system:
  ◦ vulva ◦ cervix ◦ fallopian tube
  ◦ clitoris ◦ uterus ◦ ovary
  ◦ labia ◦ endometrium
  ◦ vagina
• gamete production (meiosis) and fertilisation
	1. relate the general structure of the male and female human reproductive systems to their functions

• four phases of the menstrual cycle:
  ◦ menstruation ◦ ovulation
  ◦ follicular phase ◦ luteal phase
	2. outline the phases of the menstrual cycle **and the changes in hormone levels during each stage**

Students learn about	Students should be able to
• **changes in levels of oestrogen, progesterone, LH and FSH in each phase, reference to Graafian Follicle and Corpus Luteum**	
• anatomical and physiological processes of pregnancy ◦ fertilisation ◦ implantation ◦ placenta formation ◦ foetus development (including zygote, **morula, blastocyst, germ layers, embryo, foetus**) ◦ labour and birth	**3.** describe pregnancy from the development of fertilised zygote to birth
• role of hormones in controlling reproduction including their influence on: ◦ puberty ◦ sperm and egg production ◦ menstrual cycle ◦ implantation ◦ growth of foetus ◦ birth ◦ production of colostrum and milk for young ◦ menopause • the roles and levels of the following hormones: ◦ testosterone ◦ **FSH** ◦ **LH** ◦ progesterone ◦ oestrogen ◦ oxytocin ◦ prolactin	**4.** model the role of hormones in the human male and female reproductive systems
• monitoring the health of the mother and developing foetus ◦ antenatal screening ◦ genetic screening ◦ postnatal screening (including for PKU)	**5.** appreciate the impact of advancements in modern technology on prenatal and postnatal care
• fertile periods for males (continuous) and females (cyclical) • natural, mechanical, surgical and chemical methods of contraception and their use (including prevention of STIs), freezing eggs • treatments for infertility based on the biology of fertility including ◦ stimulating ovulation ◦ artificial insemination ◦ intracytoplasmic sperm injection ◦ in vitro fertilisation	**6.** discuss the use and biological implications of strategies to control fertility and treatments for infertility

Students learn about	Students should be able to
Plant reproduction	

Plant reproduction

- reproductive structures in flowering plants and their functions including:
  - flowers
  - seeds
  - fruits
- adaptations of these structures dependent on whether the plant is insect or wind pollinated
- flower structures and functions including:
  - sepal
  - petal
  - stamen
  - anther
  - filament
  - stigma
  - style
  - ovary
  - carpel
  - receptacle
- role of flowers in pollination
- seed structures and functions including:
  - testa
  - plumule
  - radicle
  - embryo
  - endosperm
- role of seeds in producing growth regulators in stimulating growth of fruit tissues
- methods of fruit and seed dispersal including wind, water, animal (internal and external)

7. investigate and compare the structures of insect and wind pollinated plants and relate them to their functions, use primary and secondary data to support conclusions

8. describe the role of seeds in plant reproduction

2.6. Transport and transfer (physiological processes)

- transport and transfer of materials across membranes
  - diffusion
  - osmosis
  - active transport
- factors affecting rates of osmosis:
  - temperature
  - concentration gradient
  - surface area

The urinary system

- transport and transfer of nutrients and wastes between the internal and external environment in humans

1. distinguish between diffusion, osmosis and active transport; examine the role of osmosis in food preservation and plant health

2. investigate factors affecting rates of osmosis across semi-permeable membranes, use primary data to support conclusions

3. relate the macrostructure of the urinary system to its function in filtering and removing waste; **outline the filtration of blood in the nephron**

Students learn about	Students should be able to
• urinary system (kidneys, ureters, urinary bladder, urethra) • regulation of body fluids by the kidney, site of filtration, reabsorption in the cortex, medulla and renal pelvis • transport of urine from kidney to urethra • **nephron structure and blood supply, structures and processes for filtering of blood and reabsorption of water, glucose, amino acids and some salts in Bowman's capsule, glomerulus, Loop of Henle, proximal convoluted tubule, distal convoluted tubule** • **role of ADH in osmoregulation**	

Digestion in the human body
• ingestion, digestion, absorption and egestion
• associated organs of digestive system including
  ◦ mouth ◦ esophagus ◦ stomach ◦ pancreas ◦ liver ◦ gallbladder ◦ small intestine ◦ large intestine ◦ rectum ◦ anus
• mechanical breakdown of food including
  ◦ role of teeth
  ◦ peristalsis
  ◦ stomach
  ◦ bile salts in emulsification
• chemical breakdown of food by enzymes and bile salts, including their
  ◦ roles
  ◦ production sites
  ◦ pH at a named location
  ◦ products of an amylase, protease and lipase
	4. model how the macrostructure of the human digestive system and associated organs and glands carry out the process of digesting fats, carbohydrates and proteins

• absorption of nutrients and water into the blood:
  ◦ villi
  ◦ hepatic portal vein – glycogen storage and deamination of proteins in the liver
  ◦ absorption of water and elimination of faeces through the large intestine
	5. describe the absorption, transport and storage of the products of digestion

Students learn about	Students should be able to
• balanced diet importance as related to health, age, gender, activity, variety of foods, sufficient water, role of dietary fibre, etc.	**6.** research the biological implications of dietary choices

Exchange of gases
• exchange of gases between the internal and external environment facilitated by the structures and function of the breathing system including macrostructure and function of the breathing tract in exchange of gases via the breathing mechanism:
  ◦ diaphragm
  ◦ intercostal muscles
  ◦ brain
  ◦ CO_2 levels
  ◦ exchange at the level of alveoli/capillaries
	7. relate the anatomy and physiology of the breathing system to its role in gaseous exchange in the lungs

• **CO_2 as a controlling factor in the breathing mechanism**	**8.** **outline the role of carbon dioxide concentration as a controlling factor in plant stomata and in the human breathing system**

The human circulatory system
• structures of the heart including:
  ◦ septum
  ◦ atria
  ◦ ventricles
  ◦ arteries
  ◦ veins
  ◦ valves
  ◦ cardiac muscle tissue
	9. investigate the structures of the heart and relate them to their functions, use primary and secondary data to support conclusions

• transport of materials within humans:
  ◦ two-circuit circulatory system – pulmonary and systemic
  ◦ pathways of blood circulation – pulmonary, systemic, portal
	10. model the interaction between the circulatory and other human body systems in facilitating transport of materials around the body

• role of pacemaker in regulating heartbeat (cardiac cycle not required); heart sustained through its own blood supply via coronary arteries and cardiac veins	**11.** outline heartbeat and its control by the pacemaker, pulse, blood pressure and the cardiac blood supply

• Composition of blood, structure and role of
  ◦ red blood cells
  ◦ white blood cells
  ◦ platelets
  ◦ plasma
  ◦ blood groups
  ◦ Rhesus factors
	12. relate the composition of the blood to its functions; appreciate the value of knowledge on blood grouping for human health

Students learn about	Students should be able to
	13. distinguish between arteries, veins and capillaries based on their macrostructures and role in the circulatory system of humans

Transport and transfer in plants
• plant structures to facilitate transport and transfer including:
  • leaves and lenticels
  • root and shoot system (root hairs, root cortex) and its associated tissues - dermal, ground, vascular (xylem and phloem)
	14. relate the structure of the root, stem and leaf and their associated tissues with their function

• structures and processes allowing for uptake and transfer of water and minerals in plants:
  • osmosis, diffusion, **root pressure, cohesion and tension, transpiration**, and stomata)
  • carbon dioxide (respiring cells and stomata)
  • photosynthetic products, **CO_2 as a controlling factor in plant stomata**
	15. explain the transport of water, minerals, carbon dioxide and photosynthetic products in the plant

• factors affecting rate of transpiration including:
  • air movement
  • temperature
  • surface area
  • presence or absence of cuticle
  • light intensity
  • CO_2 concentration
	16. investigate factors affecting the rate of transpiration in plants, use primary and secondary data to support conclusions

Strand 3: Interactions of Life

In this strand, students look at the systems of the living world at different scales. As they investigate interactions of individuals and groups in ecosystems, they learn that no organism in nature is independent of the systems in which it lives, functions and dies.

From common matter to diverse ecosystems, students develop and use models to explain interdependence in nature and the transfer of matter and energy through the biosphere. Through a knowledge of evolution, they explain how adaptations of living things suit specific functions allowing for species survival.

As they learn how the living and non-living worlds interact to cycle and recycle nutrients, they appreciate that no biological process can exist in isolation from its surroundings.

In this strand, students learn how life interacts with life, with the non-living world and with the modern world. They learn how knowledge and innovation interact with the information of life through genetic engineering, DNA sequencing and bioinformatics. They consider the role of microorganisms and how their structures and functions make them suitable for many advances in biotechnology.

Strand 3 Learning Outcomes

Students learn about	Students should be able to
3.1. Ecology, ecosystems, biodiversity	
	1. outline what is meant by the biosphere, ecosystems, habitats, biodiversity
• exploring local ecosystems through engagement with current news and local media • biodiversity loss having environmental, economic, social and cultural impacts	**2.** discuss the impact of biodiversity loss in local ecosystems and the important role conservation plays in limiting biodiversity loss **3.** evaluate primary or secondary data relating to the effects of human activity on species diversity
• **species diversity index, Ds, the variety of species in a given area, calculated using the Simpson's Diversity Index Equation** • $Ds = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$ • **n = total number of organisms of a particular species** • **N = total number of organisms of all species**	**4. model species diversity in ecosystems using the Simpson's Diversity Index equation**

• factors that determine the carrying capacity for plants and animals in ecosystems:
  • abiotic: water, oxygen, space, temperature, soil
  • biotic: food, disease, competition, predation
	5. illustrate how limiting factors determine the carrying capacity for species in Irish ecosystems

Students learn about	Students should be able to
• **S-population curves in resource-limited environments, J-population curves in environment with unlimited resources**	6. **consider, using population curves, how the carrying capacity for species in irish ecosystems varies depending on limiting factors**

• using models for the movement of matter and energy through ecosystems to explain and predict the impact of change
  • trophic levels
  • food chains and webs
  • pyramids of numbers
    • **shapes**
    • **limitations**
  • **pyramids of biomass**
	7. consider how nutrients are transferred from one trophic level to the next, taking into account the loss of energy at each trophic level
	8. outline the use of pyramids of numbers in the study of ecosystems
	9. **compare the use of pyramids of numbers and pyramids of biomass in the study of ecosystems.**
	10. outline the concept of the niche, using examples as it applies to adaptations of organisms in ecosystems.

• ecological investigation:
  • observation and collection methods (traps, pooter, nets, etc.)
  • classification systems to identify organisms
  • qualitative and quantitative surveys
  • measurement of abiotic factors (air, ground, aquatic, edaphic) including water, oxygen, space, temperature, soil, aspect, wind speed, slope
  • biotic factors (predation, symbiosis – **mutualism, commensalism, parasitism, competition**)
	11. use primary data gathered from a chosen ecosystem to:
	  • model a habitat in the ecosystem including its size, species, relevant biotic and abiotic factors
	  • investigate quantitatively the impact of variation in abiotic factors on the distribution and abundance of a species
	  • explain the feeding and **symbiotic relationships** that occur between organisms

3.2 Microorganisms and nutrient cycling
• organisms involved in nutrient cycling:
  • structure of a bacterial cell and *Rhizopus* fungus
  • nutrition – autotrophic, heterotrophic, saprophytic, parasitic
  • cellular nature of bacteria/fungi (prokaryotic/eukaryotic)
	1. distinguish between bacteria and fungi in terms of structure, nutrition, and cellular nature

Students learn about	Students should be able to

• factors influencing growth of microorganisms:
  • pH
  • nutrients
  • water
  • external solute concentrations
  • temperature
  • presence of antibacterial/antifungal chemicals
	2. investigate factors affecting the growth of microorganisms, use primary and secondary data to support conclusions

• use of microorganisms in a wide range of industries including
  • pharmaceutical
  • medical
  • agricultural
  • food production
• **growth curves of microorganisms – lag, log, stationary, decline/death, survival.**
• **knowledge of growth curves to increase yields of products in industries**
	3. discuss the importance of microorganisms in industries

• the microbiome playing a significant role in human health within the gastrointestinal tract:
  • digestion
  • immune signalling
  • metabolic health
• soil microbiomes responsible for cycling of multiple nutrients
• climate warming influences the functioning of soil microbiomes
	4. outline the concept of a microbiome; explore the role of microbiomes in promoting human health and nutrient cycling in soils

• biogeochemical cycles – nitrogen and carbon (names of microorganisms not required) • decomposers (bacteria and fungi)	**5.** model the carbon cycle with reference to the roles of photosynthesis, respiration, decomposers, fossil fuels and carbon sinks **6.** model the nitrogen cycle with reference to nitrogen fixation, nitrification, decomposition, denitrification **7.** evaluate ethical and sustainability issues associated with the cycling of nutrients
• carbon sinks – plants, algae, phytoplankton, bogs, etc. • the role biology will play in developing a post-fossil fuel world	**8.** discuss the link between atmospheric carbon dioxide, methane and climate change; evaluate biological strategies to reduce atmospheric levels of these gases

Students learn about	Students should be able to

3.3. Information of life – genetic engineering
• genetic engineering, including earlier methods using plasmid or other vectors, the process outlined as
  • DNA isolation
  • cutting (with restriction enzymes)
  • ligation
  • transformation and expression
	1. outline the concept of genetic engineering and its applications

	2. outline what is meant by DNA profiling and its potential uses
• **DNA extraction, polymerase chain reaction (PCR), gel electrophoresis**	3. **model the steps involved in generating a DNA profile**
• **sequencing data (nucleotide bases) – generate a collection of DNA fragments, each of which is one nucleotide shorter than the next, and separated on a gel electrophoresis**	4. **outline the principle of DNA sequencing**
• the value of technology in analysing large quantities of genetic information to identify patterns and search for anomalies	5. use a genome database to search for alleles that are known to cause (or be responsible for) specific genetic diseases
	6. investigate patterns using a DNA profile, use primary or secondary data to support conclusions
• genetic data access and use (agriculture, health, industry, reproduction, forensics, etc) • genetic modification • DNA testing • uses of stem cells (therapeutic, cloning)	7. discuss the ethical issues arising from advancements in genetic technologies

Teaching for student learning

Senior cycle students are encouraged to develop the knowledge, skills, values and dispositions that will enable them to become more independent in their learning and to develop a lifelong commitment to improving their learning.

Leaving Certificate Biology supports the use of a wide range of teaching and learning approaches that respond to the strengths, needs and interests of all students. The course is student-centred in its design and emphasises a practical experience of biology for each learner. As students progress, they will develop skills that are transferable across different tasks and different disciplines, enabling them to make connections between biology, other subjects, and everyday experiences. Providing opportunities for students to develop a range of inquiry skills will be necessary to progress along the continuum of inquiry. Teachers are best positioned to make professional judgements on how to develop these skills with their students through an appropriate balance of explicit instruction and inquiry-based approaches. By engaging in well-structured group discussions, students will develop skills in reasoned argument, listening to each other and reflecting on their own work and that of others.

Modelling is at the heart of what biologists do, therefore it is important that students studying Leaving Certificate Biology learn to use words, diagrams, equations, physical models or simulations to represent ideas, structures, processes and systems. They will develop and use models to describe, explain, make predictions and solve problems, recognising that all models have limitations and can be refined based on new information gained through scientific inquiry. Scientific practices are best learned by doing, and in planning for teaching and learning, teachers should provide ample opportunity for students to engage with the scientific practices set out in the unifying strand. Whilst the contextual strands set out situations where students are required to gather primary data to verify observations and mathematical relationships, this is a minimum requirement and it is not expected that practical opportunities would be limited to these situations.

Through cross-cutting themes, students will integrate their knowledge and understanding of biology with the ethical, social, economic and environmental implications and applications of biology. Increasingly, arguments between scientists extend into the public domain. By critically evaluating scientific texts and debating public statements about science, students will engage with contemporary issues in biology that affect their everyday lives. They will learn to interrogate and interpret data—primary data that they collect themselves as well as secondary data collected by others—a skill which has a value far beyond biology wherever data are used as evidence to support argument. By providing an opportunity to examine and debate reports about contemporary issues in science, Leaving Certificate Biology will enable students to develop an appreciation of the social context of science. They will develop skills in scientific communication by collaborating to generate perspectives and present them to their peers.

The variety of activities that students engage in will enable them to take charge of their own learning by setting goals, developing action plans, and receiving and responding to assessment feedback. Students vary in the amount and type of support they need to be successful. Levels of demand in any learning activity will differ as students bring different ideas and levels of understanding to it. The use of strategies such as adjusting the level of skills required, varying the amount and the nature of teacher intervention, and varying the pace and sequence of learning promotes inclusivity. As well as varied teaching strategies, varied assessment strategies will support learning and provide information that can be used as feedback so that teaching and learning activities can be modified in ways that best suit individual students. By setting appropriate and engaging tasks, asking questions of varying cognitive demand and giving feedback that promotes learner autonomy, assessment will support learning as well as summarising achievement.

Digital technology

Digital technology can enhance learning, teaching and assessment, creating opportunities for students to develop scientific knowledge and skills and digital media literacy in ways that cannot be achieved without the use of technology. As students engage with Leaving Certificate Biology, they have opportunities to use digital technology in a range of ways. For example, they may use digital technology to:

- collect, record, analyse and display data and information appropriately
- visualise, predict, explain, and model the organisation, structures, processes, and interactions of living things
- access and analyse large datasets (e.g. databases of genetic information) in ways that non-digital techniques of data collection/analysis cannot
- develop a deeper understanding of data through choosing the right tools for data collation, visualisation, analysis, and representation of results
- develop and improve investigative research, communication, and report writing skills
- become more independent learners through, for example, appropriate online supports
- enhance their experience in the biology laboratory
- develop their understanding of how biologists use digital technology in their work.

Assessment

Assessment in senior cycle involves gathering, interpreting, using and reporting information about the processes and outcomes of learning. It takes different forms and is used for a variety of purposes. It is used to determine the appropriate route for students through a differentiated curriculum, to identify specific areas of strength or difficulty for a given student and to test and certify achievement. Assessment supports and improves learning by helping students and teachers to identify next steps in the teaching and learning process.

As well as varied teaching strategies, varied assessment strategies will support student learning and provide information to teachers and students that can be used as feedback so that teaching and learning activities can be modified in ways that best suit individual learners. By setting appropriate and engaging tasks, asking questions and giving feedback that promotes learner autonomy, assessment will support learning and promote progression, support the development of student key competencies and summarise achievement

Assessment for certification

Assessment for certification is based on the rationale, aims and learning outcomes of this specification. There are two assessment components: a written examination and an additional assessment component comprising a Biology in Practice Investigation. The written examination will be at higher and ordinary level. The Biology in Practice Investigation will be based on a common brief. Each component will be set and examined by the State Examinations Commission (SEC).

In the written assessment, Leaving Certificate Biology will be assessed at two levels, Higher and Ordinary (Table 1, page 12). Examination questions will require students to demonstrate learning appropriate to each level. Differentiation at the point of assessment will also be achieved through the stimulus material used, and the extent of the structured support provided for students at different levels.

Assessment component	Weighting	Level
Biology in Practice Investigation	40%	Common brief
Written examination	60%	Higher and Ordinary level

Table 2: Overview of Assessment for Certification

Additional assessment component: Biology in Practice Investigation

The Biology in Practice Investigation provides an opportunity for students to display evidence of their learning throughout the course, in particular, the learning set out as outcomes in the unifying strand. It involves students completing a piece of work during the course and, in Year 2, submitting for marking to the State Examinations Commission (SEC), evidence of their ability to conduct scientific research on a particular issue and to use appropriate primary data to investigate aspects of that issue. It has been designed to be naturally integrated into the flow of teaching and learning and to exploit its potential to be motivating and relevant for students, to draw together the learning outcomes and cross-cutting themes of the course and to highlight the relevance of learning in Biology to their lives.[2]

The Biology in Practice Investigation provides opportunities for students to pursue their interests in Biology, to make their own investigative decisions, acquire a depth of conceptual understanding and self-regulate their own learning.

Investigation brief

An *Investigation Brief* will be published annually by the SEC in term two of Year 1 of the course. As well as setting out the specific requirements of the Biology in Practice Investigation, the brief will:

- allow students to develop their thinking and ideas on areas they would like to pursue, related to the brief
- facilitate teachers and students in their planning
- include stimulus material to set a context for the investigation
- allow students to develop an investigative log that they can draw upon as they complete their investigation.

Building on their learning to date, students will learn more about the nature of investigation through research and experimentation. Students should be empowered in realising that research and experimentation is more about engaging with and learning from the process, rather than seeking a *perfect answer*. Students should give an authentic account of how their investigative work unfolds, discuss and explain the outcomes of their investigation and how they might revise aspects of the process.

To complete the Biology in Practice Investigation, students carry out the following.

- Scientific research on an issue related to the brief. They gather, process and evaluate information from secondary sources. The knowledge gained from this phase of the investigation may help to inform their experimental work.
- An experiment related to an issue within the brief. They generate a hypothesis, plan, and design their experiment. They carry out their experiment and gather primary data. Once they have gathered their primary data, they analyse the data and form conclusions.

Students develop an evidence-based argument in response to the brief. Upon completion, students submit a report of their investigation in Year 2 in a format prescribed by the SEC.

Schools have a high degree of autonomy in planning and organising the completion of the investigation. A separate document, *Guidelines for the Biology in Practice Investigation*, gives guidance on a range of matters related to the organisation, implementation, and oversight of the investigation.

[2] It is envisaged that the AAC will take up to 20 hours to complete. Further details will be provided in the Guidelines to support the Biology in Practice Investigation.

Descriptors of quality for the Biology in Practice investigation

The descriptors below relate to the learning achieved in the Biology in Practice Investigation. In particular, the investigation requires students to:

- consider issues related to real-world applications of biology
- demonstrate investigative skills
- relate their investigative work to the work of scientists in society
- communicate their findings appropriately and effectively

	Students demonstrating a high level of achievement	Students demonstrating a moderate level of achievement	Students demonstrating a low level of achievement
Knowledge and understanding	engage thoroughly with the concepts being investigated; explain clearly and accurately, using appropriate means, the biological phenomena involved; where applicable, pose a testable hypothesis that is underpinned by biological theory and clearly describe the purpose of the investigation.	have a good engagement with the concepts being investigated; describe the biological phenomena involved; where applicable, pose a testable hypothesis and outline the purpose of the investigation.	have a limited engagement with the concepts being investigated; outline the biological phenomena involved; are provided with a testable hypothesis to investigate.
Demonstrate investigative skills (design and method)	use clear, thorough, and appropriate investigative design and methods to collect primary data, leading to high quality data, presentation, and analysis.	use clear and appropriate investigative design and methods to collect primary data, leading to good quality data, presentation, and analysis.	use unclear investigate design and methods to collect primary data, leading to limited data, presentation, and analysis.
Demonstrate investigative skills (analysis and conclusions)	draw valid conclusions justified by the data and relating to any hypotheses made; thoroughly evaluate the investigation acknowledging sources of error in the investigative design.	draw conclusions that relate to any hypotheses made, identify potential sources of error in the investigative design.	draw limited conclusions. Potential sources of error in the investigative design are not identified.
Relate their investigative work to the work of scientists in society	offer a considered reflection that locates the outcomes of the investigation within broader issues relating to the work of a scientist or science and society.	reflect on how the outcomes of the investigation relate to the work of a scientist or science and society.	make limited links between the outcomes of the investigation and the work of a scientist or science and society.

Table 3: Descriptors of Quality: Biology in Practice Investigation

Written examination

The written examination will consist of a range of question types. The senior cycle key competencies (Figure 2) are embedded in the learning outcomes and will be assessed in the context of the learning outcomes. The written examination paper will include a selection of questions that will assess, appropriate to each level:

- the learning described in the three contextual strands of the specification and the unifying strand
- application of Biology to issues relating to the cross-cutting themes—sustainability, health, and technology.

Reasonable accommodations

This Leaving Certificate Biology specification requires that students engage with the nature of the subject on an ongoing basis throughout the course. The assessment for certification in Leaving Certificate Biology involves a written examination worth 60% of the available marks and an additional component worth 40%. In this context, the scheme of Reasonable Accommodations, operated by the State Examinations Commission (SEC), is designed to assist students who would have difficulty in accessing the examination or communicating what they know to an examiner because of a physical, visual, sensory, hearing, or learning difficulty. The scheme assists such students to demonstrate what they know and can do, without compromising the integrity of the assessment. The focus of the scheme is on removing barriers to access, while retaining the need to assess the same underlying knowledge, skills, values, and dispositions as are assessed for all other students and to apply the same standards of achievement as apply to all other students The Commission makes every effort when implementing this scheme to accommodate individual assessment needs through these accommodations.

There are circumstances in which the requirement to demonstrate certain areas of learning when students are being assessed for certification can be waived or exempted, provided that this does not compromise the overall integrity of the assessment.

More detailed information about the scheme of Reasonable Accommodations in the Certificate Examinations, including the accommodations available and the circumstances in which they may apply, is available from the State Examinations Commission's Reasonable Accommodations Section.

Before deciding to study Leaving Certificate Biology, students, in consultation with their school and parents/guardians should review the learning outcomes of this specification and the details of the assessment arrangements. They should carefully consider whether or not they can achieve the learning outcomes, or whether they may have a special educational need that may prevent them from demonstrating their achievement of the outcomes, even after reasonable accommodations have been applied. It is essential that if a school believes that a student may not be in a position to engage fully with the assessment for certification arrangements, they contact the State Examinations Commission.

Leaving Certificate Grading

Leaving Certificate Biology will be graded using an 8-point grading scale. The highest grade is a Grade 1; the lowest grade is a Grade 8. The highest seven grades (1-7) divide the marks range 100% to 30% into seven equal grade bands 10% wide, with a grade 8 being awarded for percentage marks of less than 30%. The grades at Higher level and Ordinary level are distinguished by prefixing the grade with H or O respectively, giving H1-H8 at Higher level, and O1-O8 at Ordinary level.

Grade	% marks
H1/O1	90 – 100
H2/O2	80 < 90
H3/O3	70 < 80
H4/O4	60 < 70
H5/O5	50 < 60
H6/O6	40 < 50
H7/O7	30 < 40
H8/O8	< 30

Table 4: Leaving Certificate grading scale.

Appendix 1 Glossary of action verbs

Action verb	Students should be able to
Analyse	study or examine something in detail, break down in order to bring out the essential elements or structure; identify parts and relationships, and to interpret information to reach conclusions
Apply	select and use information and/or knowledge and understanding to explain a given situation or real circumstances
Appreciate	recognise the meaning of, have a practical understanding of
Classify	group things based on common characteristics
Compare	give an account of the similarities and (or) differences between two (or more) items or situations, referring to both (all) of them throughout
Conduct	perform an activity
Consider	describe patterns in data; use knowledge and understanding to interpret patterns; make predictions and check reliability
Describe	develop a detailed picture or image of, for example a structure or a process, using words or diagrams where appropriate; produce a plan, simulation or model
Design	conceive, create and execute according to plan
Discuss	offer a considered, balanced review that includes a range of arguments, factors or hypotheses; opinions or conclusions should be presented clearly and supported by appropriate evidence
Distinguish	make the differences between two or more concepts or items clear
Evaluate (data)	collect and examine data to make judgments and appraisals; describe how evidence supports or does not support a conclusion in an inquiry or investigation; identify the limitations of data in conclusions; make judgments about the ideas, solutions or methods
Evaluate (ethical judgement)	collect and examine evidence to make judgments and appraisals; describe how evidence supports or does not support a judgement; identify the limitations of evidence in conclusions; make judgments about the ideas, solutions or methods
Examine	consider an argument or concept in a way that uncovers the assumptions and relationships of the issue
Explain	give a detailed account including reasons or causes
Explore	observe, study, in order to establish facts
Identify	recognise patterns, facts, or details; provide an answer from a number of possibilities; recognize and state briefly a distinguishing fact or feature
Illustrate	use examples to describe something
Investigate	observe, study, or make a detailed and systematic examination, in order to establish facts and reach new conclusions
Interpret	use knowledge and understanding to recognise trends and draw conclusions from given information
Justify	give valid reasons or evidence to support an answer or conclusion
Measure	quantify changes in systems by reading a measuring tool

Action verb	Students should be able to
Model	represent an idea, structure, process or system through a variety of means such as words, diagrams, equations, physical models or simulations; use models to describe, explain, make predictions and solve problems, recognising that all models have limitations
Organise	arrange; to systematise or methodise
Outline	give the main points; restrict to essentials
Plan	devise or project a method or a course of action
Pose	put forward for consideration
Predict	give an expected result of an event; explain a new event based on observations or information using logical connections between pieces of information
Produce	bring into existence by intellectual or creative ability
Recognise	identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon
Reflect	consider in order to correct or improve
Research	inquire specifically, using involved and critical investigation
Relate	associate, giving reasons
Review	re-examine deliberately or critically, usually with a view to approval or dissent; to analyse results for the purpose of giving an opinion
Use	apply knowledge or rules to put theory into practice

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Published August 2024.