

Units

Unit 1: Cells and multicellular organisms

In Unit 1, students explore the ways biology is used to describe and explain how the structure and function of cells and their components are related to the need to exchange matter and energy with their immediate environment. An understanding of the structure and function of cells is essential to appreciate the processes vital for survival. Students investigate the structure and function of cells and multicellular organisms. They examine the structure and function of plant and animal systems at cell and tissue levels in order to analyse how they facilitate the efficient provision or removal of materials.

Contexts that could be investigated in this unit include stem cell research, animal ethics, organ and tissue transplantation, bio-artificial organs and photosynthesis productivity. Through the investigation of these contexts, students may explore the ethical considerations that apply to the use of living organisms in research.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of the relationship between structure and function of cells and multicellular organisms. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in conducting real or virtual laboratory work and carrying out microscopic examination of cells and tissues. They use these skills to construct and use models to describe and interpret data about the functions of cells and organisms and to explain cellular processes.

Unit objectives

1. Describe ideas and findings about cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.
2. Apply understanding of cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.
3. Analyse data about cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.
4. Interpret evidence about cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.
5. Evaluate processes, claims and conclusions about cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.
6. Investigate phenomena associated with cells as the basis of life, exchange of nutrients and wastes, and cellular energy, gas exchange and plant physiology.

Subject matter

Topic 1: Cells as the basis of life (15 hours)

Science understanding

- Compare prokaryotic and eukaryotic cells.
- Identify key organelles and their functions, including the nucleus, mitochondria, rough ER, ribosomes, smooth ER, Golgi apparatus, lysosomes, vacuoles and chloroplasts.
- Describe how stem cells originate through the process of mitosis and differentiate into specialised cells to form tissues.
- Distinguish between unipotent, multipotent, pluripotent and totipotent stem cells.
- Describe how the hierarchical organisation of cells, tissues, organs and systems allow multicellular organisms to
 - obtain nutrients, e.g. digestive and circulatory systems
 - exchange gases, e.g. respiratory and circulatory systems
 - remove wastes, e.g. respiratory, circulatory and excretory systems.
- Explain that each body system contains specialised cells and tissues that are structurally suited to function, including
 - size and shape (SA:V ratio)
 - organelle composition.
- Describe the structure and function of the cell membrane based on the fluid mosaic model, including the role of protein channels, phospholipids, cholesterol and glycoproteins.
- Explain how the cell membrane regulates movement of substances into and out of the cell via
 - osmosis
 - simple diffusion
 - facilitated diffusion
 - protein-mediated active transport
 - endocytosis and exocytosis.
- Compare active and passive transport.
- Explain how the size of a cell is limited by surface area-to-volume ratio and rate of diffusion.
- Interpret data from an experiment investigating the effect of surface area-to-volume ratio on the rate of diffusion.

Science as a human endeavour

- Appreciate that
 - to make sense of the complexity of biological systems, scientists often divide them into simpler components that are easier to study, but at each level of the biological hierarchy, new properties emerge
 - pluripotent stem cells have the potential to be grown into specialised cells that can be used to repair or replace ailing organs and tissues. Advances in technology have allowed scientists to reprogram cells to become pluripotent
 - the use of animals in research has played an important role in furthering scientific understanding of the structure and function of multicellular organisms. Ethical treatment of animals as sentient beings has been accepted as a global principle in research and the three strategies of replacement, reduction and refinement form the basis of many international guidelines.

Science inquiry

- Use a light microscope or photographs to
 - view tissues from the respiratory, circulatory, excretory, digestive and/or plant systems
 - compare epithelial, connective, muscle and nervous tissues
 - calculate total magnification and field of view.
- Compare organelle composition of different cell types using electron micrographs.
- Investigate the effect of surface area-to-volume ratio on rate of diffusion.
- Explore the safety, ethics and efficacy of stem cell technologies.

Topic 2: Exchange of nutrients and wastes (15 hours)

Science understanding

- Describe the structure and function of carbohydrates, proteins and lipids.
- Describe the roles of amylase, protease and lipase in chemical digestion.
- Explain how structural features of exchange surfaces in the digestive and circulatory systems of mammals (e.g. villi and capillaries) allow for efficient nutrient exchange.
- Describe how closed circulatory systems facilitate the efficient transport of materials to and from all cells in the body.
- Identify the parts of a nephron and their functions in the production of urine, i.e. glomerulus, Bowman's capsule, proximal tubule, Loop of Henle, distal tubule and collecting duct.
- Explain how glomerular filtration, selective reabsorption and secretion across nephron membranes contribute to the removal of waste.
- Explain how metabolic processes, such as digestion, are controlled and regulated by enzymes.
- Describe the structure and function of enzymes, including the role of the active site.
- Compare the induced-fit and lock-and-key models of enzyme function.
- Explain how enzyme activity is affected by factors such as temperature, pH, presence of inhibitors and substrate concentration.
- Interpret data from an experiment investigating factors affecting enzyme activity.

Science as a human endeavour

- Appreciate how understanding the anatomy and physiology of different body systems allows medical professionals to predict, diagnose, monitor and treat disease.

Science inquiry

- Investigate the effect of temperature/pH/substrate concentration on the reaction rate of different enzymes.
- Explore how understanding enzymes, and their roles in metabolism, can be used to diagnose and treat metabolic disease.

Topic 3: Cellular energy, gas exchange and plant physiology (15 hours)

Science understanding

- Distinguish between catabolism and anabolism.
- Explain how ATP allows energy from catabolic reactions to be used in anabolic reactions.
- Describe the process of aerobic respiration, identifying the location in the cell and net inputs and outputs of
 - glycolysis
 - Krebs cycle and electron transport chain
 - the overall reaction ($\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + 36\text{--}38 \text{ ATP}$).
- Compare aerobic and anaerobic respiration.
- Explain how structural features of exchange surfaces in the respiratory and circulatory systems of mammals (alveoli and capillaries) allow for efficient gas exchange.
- Analyse data to predict the direction that materials will be exchanged between
 - alveoli and capillaries
 - capillaries and muscle tissue.
- Describe the process of photosynthesis, identifying the location in the cell and net inputs and outputs of
 - light-dependent reactions
 - light-independent reactions
 - the overall reaction ($6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$).
- Compare the structure and function of xylem and phloem tissues.
- Explain how stomata and guard cells facilitate gas exchange in plants.
- Interpret data from an experiment investigating the effect of light intensity, temperature, wind or humidity on the rate of transpiration.

Science as a human endeavour

- Appreciate how scientists use their understanding of natural systems to develop new technologies.

Science inquiry

- Investigate
 - factors affecting the rate of transpiration in different plants.
 - adaptations that allow for efficient nutrient and/or gas exchange in plants or animals.
- Explore how understanding natural systems can be used to design new technologies, e.g. artificial leaves that convert solar energy into liquid fuel.

Unit 2: Maintaining the internal environment

In Unit 2, students explore the ways biology is used to describe and explain the responses of homeostatic mechanisms to stimuli and the human immune system. An understanding of personal and communal responses is essential to appreciate personal lifestyle choices and community health. Students develop scientific skills and conceptual understanding in homeostasis, the immune system and the relationships between global, community and individual immunity. They examine geographical and population data to analyse strategies that may have personal and communal consequences.

Contexts that could be investigated in this unit include historical and current epidemics and pandemics. Through the investigation of these contexts, students may explore immunisation, quarantine, management strategies and travel preparation (both local and international).

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of controlling the internal environment. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in the application of technology, scientific practicals and investigations, analysis and evaluation. These skills allow them to describe and explain relationships between external and internal stimuli on controlling the internal environment.

Unit objectives

1. Describe ideas and findings about homeostasis, and infectious disease and epidemiology.
2. Apply understanding of homeostasis, and infectious disease and epidemiology.
3. Analyse data about homeostasis, and infectious disease and epidemiology.
4. Interpret evidence about homeostasis, and infectious disease and epidemiology.
5. Evaluate processes, claims and conclusions about homeostasis, and infectious disease and epidemiology.
6. Investigate phenomena associated with homeostasis, and infectious disease and epidemiology.

Subject matter

Topic 1: Homeostasis (24 hours)

Science understanding

- Explain how the nervous and endocrine systems use negative feedback to coordinate responses to internal/external stimuli and maintain homeostasis (stimulus-response model).
- Identify the different types of sensory receptors and their stimuli, including chemoreceptors, thermoreceptors, mechanoreceptors, photoreceptors and nociceptors.
- Describe the structure and function of nerve cells, including dendrites, soma, body, axon, myelin sheath, nodes of Ranvier, axon terminal and synapse.
- Distinguish between sensory neurons, interneurons and motor neurons.
- Explain the passage of a nerve impulse in terms of transmission of an action potential and synaptic transmission, referring to neurotransmitters, receptors, synaptic cleft, vesicles, postsynaptic and presynaptic neurons and signal transduction.
- Describe how hormones relay messages to cells displaying specific receptors via the circulatory or lymphatic system.
- Explain how receptor binding alters cellular activity, recognising that a cell's sensitivity to a specific hormone is directly related to the number of receptors it displays for that hormone.
- Analyse feedback-control diagrams to identify the stimulus, receptor/s, control centre, effector/s and communication pathway/s in different scenarios.
- Explain thermoregulatory mechanisms of endotherms, including
 - structural features: brown adipose tissue, insulation
 - behavioural responses: kleptothermy, hibernation, aestivation and torpor
 - physiological mechanisms: evaporative heat loss, thermogenesis and vasomotor control.
- Explain thermoregulation in humans, including the role of sweating, shivering, vasodilation and vasoconstriction using feedback control diagrams.
- Explain osmoregulation in humans, including the role antidiuretic hormone (ADH) and the kidney using feedback control diagrams.
- Explain how structural and homeostatic mechanisms maintain water balance in plants, including the roles of stomata, vacuoles, cuticle and abscisic acid.
- Interpret data from an experiment comparing the number and distribution of stomata in plants adapted to different environments.

Science as a human endeavour

- Appreciate that
 - living things need to regulate their internal environment so that factors such as pH and temperature are within the tolerance ranges of enzymes that regulate metabolism
 - understanding natural systems can lead to advances in technology and engineering. For example, computer models of human thermoregulation responses, including heat transfer, perspiration, respiration and blood flows, have been developed for use in the design of clothing and environments that aim to protect humans from hyper- and hypothermia.

Science inquiry

- Investigate
 - tolerance limits for water or salt balance on plant growth
 - structural, behavioural, physiological and/or homeostatic mechanisms used by different species to control heat exchange/metabolic activity/water balance
 - the use of hormones in agriculture.
- Compare the number and distribution of stomata in plants adapted to different environments.

Topic 2: Infectious disease and epidemiology (21 hours)

Science understanding

- Distinguish between infectious and non-infectious disease.
- Identify key features of prions, viruses, bacteria, fungi, protists and parasites.
- Explain how adherence factors, invasion factors, capsules and toxins affect pathogenesis.
- Explain how host cells recognise self from non-self.
- Identify the three lines of defence in vertebrates
 - the innate immune response: skin and mucous membranes (non-specific)
 - inflammatory response and complement system (non-specific)
 - adaptive immune response (specific).
- Describe the inflammatory response, including the roles of
 - prostaglandins and vasodilation
 - neutrophils and macrophages
 - natural killer cells.
- Explain the adaptive immune response, including the
 - humoral response (B lymphocytes, antibodies)
 - cell-mediated response (T lymphocytes)
 - role of memory cells.
- Compare active and passive immunity, both naturally acquired and artificially acquired.
- Interpret long-term immune response data.
- Describe the innate immune responses in plants, including
 - physical defence strategies: barriers and leaf structures
 - chemical defence strategies: plant defensins and production of toxins.
- Interpret data from an experiment investigating the effect of an antimicrobial agent on the growth of a microorganism.
- Describe modes of disease transmission, including direct contact, contact with body fluids, contaminated food, contaminated water and disease-specific vectors.

- Explain how the following factors affect the spread of disease
 - persistence of pathogens within host
 - transmission mechanism
 - proportion of the population that are immune or have been immunised
 - mobility of individuals in the affected population.
- Explain how personal hygiene measures, contact tracing and quarantine are used to control the spread of disease.
- Analyse data to
 - predict outbreaks
 - determine the source of an outbreak
 - infer the mode of disease transmission
 - determine the effectiveness of different strategies in controlling the spread of disease.

Science as a human endeavour

- Appreciate that
 - for thousands of years, First Nations peoples' knowledges of natural antiseptics and bush medicines have been used to prevent and treat infections
 - scientific advancement and the development of complex models often requires contribution from multiple individuals across a range of disciplines
 - Australia has an advantage over many other countries because its borders are easier to protect against the influx of disease-carrying materials and organisms. However, as global trade and air travel become more prevalent, it is increasingly important for Australia to protect its agriculture industry and environment through quarantine measures. These include surveillance, monitoring, examination and clearance activities and conform to policies and protocols that are based on scientific data and risk analysis
 - mass vaccination programs are more successful when informed by disease outbreak models.

Science inquiry

- Investigate
 - the effect of an antimicrobial agent on the growth of a microorganism (via the measurement of zones of inhibition) in either a laboratory or virtual context
 - how the transmission of disease is facilitated by regional and global movement
 - the effectiveness of health programs for the prevention and eradication of infectious diseases, e.g. smallpox, influenza, polio, Ebola, cholera, malaria.
- Explore
 - how First Nations peoples' knowledges of natural antiseptics and bush medicines are used to prevent and treat infections
 - how the work of scientists such as Rosalyn Sussman Yalow and Peter C Doherty has improved our understanding of infectious disease and the immune response
 - vaccine development.