# Unit 3: Biodiversity and the interconnectedness of life

In Unit 3, students explore the ways biology is used to describe and explain: the biodiversity within ecosystems; a range of biotic and abiotic components; species interactions; adaptations of organisms to their environment; principles of population dynamics; and how classification systems are used to identify organisms and aid scientific communication. An understanding of the structure of ecosystems, the processes involved in the movement of energy and matter in ecosystems and how environmental factors limit populations is essential to appreciate the dynamics, diversity and underlying unity of these systems. Students investigate the interactions within and between species, and the interactions between abiotic and biotic components of ecosystems. They also investigate how measurements of abiotic factors, population numbers, species diversity and descriptions of interactions between species can form the basis for spatial and temporal comparisons between ecosystems. They examine and analyse data collected from fieldwork to understand the interconnectedness of organisms, the physical environment and the impact of human activity.

Contexts that could be investigated in this unit include the local ecosystem; fishing and mining industries; habitat destruction; and ecosystem management systems. Through investigating these contexts, students may explore the impact of human activity on biodiversity, and sustainability of practices.

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 how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which scientific knowledge interacts with social, economic, cultural and ethical factors. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in sampling ecological systems, organising and analysing data and developing ecological models to describe and explain the diversity and interconnectedness of life on Earth.

## Unit objectives

1. Describe ideas and findings about biodiversity and populations, and functioning ecosystems and succession.
2. Apply understanding of biodiversity and populations, and functioning ecosystems and succession.
3. Analyse data about biodiversity and populations, and functioning ecosystems and succession.
4. Interpret evidence about biodiversity and populations, and functioning ecosystems and succession.
5. Evaluate processes, claims and conclusions about biodiversity and populations, and functioning ecosystems and succession.
6. Investigate phenomena associated with biodiversity and populations, and functioning ecosystems and succession.

## Subject matter

### Topic 1: Biodiversity and populations (20 hours)

#### Science understanding

The following subject matter can be assessed in the external assessment.

- Describe genetic, species and ecosystem diversity.
- Describe the biological species concept and identify its limitations.
- Identify the major taxa in the Linnaean system of biological classification and explain how it is used to classify and name species.
- Use dichotomous keys to identify and classify organisms.
- Use the Lincoln index ($N = \frac{M \times n}{m}$) to estimate the size of a population.
- Determine the diversity of species using measures such as species richness, evenness (relative species abundance), percentage cover, percentage frequency and Simpson's diversity index, $SDI = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$.
- Describe how sampling can be used to investigate the species diversity of a given area, considering the most appropriate
  - sampling method: random, systematic, stratified
  - sampling technique: quadrats, line transect, belt-transect, capture-recapture
  - strategies to minimise bias: size and number of samples, random-number generators, counting criteria, calibrating equipment and noting associated precision
  - measure/s of diversity.
- Describe how the distribution and abundance of species in an ecosystem are influenced by
  - biotic factors — food availability, competition for resources, predation, disease
  - abiotic factors — space, shelter, availability of water, nutrients, environmental conditions.
- Explain that ecosystems are composed of varied habitats, including microhabitats, which may impact the distribution of species (e.g. uniform, random or clumped), and therefore the validity and reliability of different sampling methods/techniques.
- Interpret data from an experiment investigating how abiotic factors affect the distribution, abundance and/or biodiversity of species in an ecosystem.
- Interpret data to classify and name ecosystems using Specht's classification system and the Holdridge life zone classification scheme.
- Identify and explain different modes of population growth, including
  - exponential growth (J-curve)
  - logistic growth (S-curve).
- Compare the reproductive strategies and growth curves of K- and r- strategists.
- Calculate population growth rate and change using birth, death, immigration and emigration data.

### Science as a human endeavour

The following subject matter may be assessed in the internal assessments.

- Appreciate that
  - methods of classification are directly related to the purpose for which the data will be used. Hierarchical systems, such as the Linnaean system, can be used to organise, analyse and communicate data about biodiversity. For example, the hierarchical nature of the Linnaean system allows scientists to infer similarities between species; however, as the system was originally based primarily on physical features, the categorisation of species does not always reflect evolutionary relatedness. Species may be re-classified as new information becomes available
  - there are multiple definitions for *species*, and each has limitations. Examples include the biological species concept, phylogenetic species concept, ecological species concept and morphological species concept
  - developments in software, computing and supercomputing have been important in ecological classification as they have enabled scientists to classify regions according to large sets of biotic and abiotic data and to compare data over time. Supercomputers have also enabled the development of large, complex models to analyse species data collected from multiple individuals in a range of locations, and to infer relationships between species, including their shared evolutionary past.

### Science inquiry

The following subject matter may be assessed in the internal assessments.

- Use the process of stratified sampling to
  - identify different habitats within an ecosystem
  - investigate changes to abiotic factors in different strata
  - investigate changes to community composition in different strata, e.g. layers of a forest
  - infer species interactions within and between strata
  - classify an ecosystem.
- Investigate
  - how abiotic factors affect the distribution and/or abundance of species in an ecosystem
  - changes in species composition along an environmental gradient
  - how environmental factors affect the global distribution of ecosystems
  - how the process of classifying ecosystems allows for effective ecosystem management.
- Compare species diversity in two spatially variant ecosystems of the same classification.

## Topic 2: Functioning ecosystems and succession (25 hours)

### Science understanding

The following subject matter can be assessed in the external assessment.

- Explain the transfer and transformation of energy as it flows through the biotic components of an ecosystem, including the
  - conversion of light into chemical energy
  - production of biomass and its interactions with components of the carbon cycle
  - loss of energy as heat.
- Analyse food chains, energy flow diagrams and ecological pyramids to determine
  - efficiencies of energy and biomass transfer
  - gross and net productivity
  - loss of energy through radiation, reflection and absorption.
- Describe the transfer and transformation of matter (water, carbon, nitrogen) as it cycles through ecosystems.
- Explain the following species interactions: predation, competition, mutualism, commensalism and parasitism.
- Describe the concept of an ecological niche.
- Explain the competitive exclusion principle.
- Explain the critical role that keystone species play in maintaining the structure of a community.
- Analyse ecological data (e.g. food webs, population data) to
  - identify keystone species
  - infer species interactions
  - predict the outcomes of removing species from an ecosystem.
- Explain how overexploitation, habitat destruction, monocultures and pollution affect community structure and ecosystem functioning.
- Explain how the carrying capacity of an ecosystem can be impacted by changes to biotic and abiotic factors, including climatic events.
- Describe the process of ecological succession.
- Distinguish between primary and secondary succession.
- Identify the features of pioneer species that make them effective colonisers.
- Explain successional changes, with reference to species interactions, abiotic factors, K- and r-selected species, biodiversity and biomass.
- Interpret ecological data to compare ecosystems across spatial and temporal scales.

### Science as a human endeavour

The following subject matter may be assessed in the internal assessments.

- Appreciate that
  - First Nations peoples' knowledges of environmental change and interactions between abiotic and biotic elements of ecosystems has developed over thousands of years and provides valuable data for understanding ecosystem dynamics. This includes knowledge of land management practices that can maintain ecosystems at specific successional points
  - some biologists have advocated for keystone species to be special targets for conservation efforts and keystone species theory has informed many conservation strategies; however, there are differing views about the effectiveness of single-species conservation (such as keystone species, flagship species or umbrella species) in maintaining complex ecosystem dynamics
  - the fossil record and sedimentary rock characteristics provide evidence of past ecosystems.

### Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate
  - species interactions, e.g. by looking for correlation in abundance data
  - the competitive exclusion principle, e.g. by studying vertical zonation on a tree
  - factors affecting carrying capacity
  - the effectiveness of single-species conservation in maintaining complex ecosystem dynamics
  - how the fossil record and sedimentary rock characteristics provide evidence of past ecosystems.
- Explore how First Nations peoples' knowledges of environmental change and interactions between abiotic and biotic elements of ecosystems inform land management practices.

# Unit 4: Heredity and continuity of life

In Unit 4, students explore the ways biology is used to describe and explain the cellular processes and mechanisms that ensure the continuity of life. An understanding of the processes and mechanisms of how life on Earth has persisted, changed and diversified over the last 3.5 billion years is essential to appreciate the unity and diversity of life.

Students investigate different factors that affect cellular processes and gene pools. They examine different patterns of inheritance and the genetic basis of the theory of evolution through natural selection to analyse the use of predictive models in decision-making.

Contexts that could be investigated in this unit include DNA profiling, gene therapy and genetically modified organisms. Through the investigation of these contexts, students may explore the impact of the development of these technologies on future society.

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 patterns of inheritance and the effect of a variety of factors on gene pools. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in modelling processes to describe and explain inheritance and population genetics.

## Unit objectives

1. Describe ideas and findings about genetics and heredity, and the continuity of life on Earth.
2. Apply understanding of genetics and heredity, and the continuity of life on Earth.
3. Analyse data about genetics and heredity, and the continuity of life on Earth.
4. Interpret evidence about genetics and heredity, and the continuity of life on Earth.
5. Evaluate processes, claims and conclusions about genetics and heredity, and the continuity of life on Earth.
6. Investigate phenomena associated with genetics and heredity, and the continuity of life on Earth.

## Subject matter

### Topic 1: Genetics and heredity (30 hours)

#### Science understanding

The following subject matter can be assessed in the external assessment.

- Describe the structure and function of DNA, genes and chromosomes in prokaryotes and eukaryotes, including
  - helical structure, nucleotide composition (nitrogenous base + sugar + phosphate), complementary base pairing, hydrogen bonds
  - introns and exons, promoter region
  - homologous chromosomes (i.e. sister chromatids, centromeres, telomeres, gene loci, alleles), role of histones
  - circular chromosomes (i.e. prokaryotes, mitochondria, chloroplasts) and plasmids.
- Describe the process of DNA replication with reference to helicase, DNA polymerase and the joining of Okazaki fragments.
- Explain how errors in DNA replication and damage by physical/chemical factors in the environment can lead to point and frameshift mutations.
- Describe the process of meiosis and explain how crossing over, independent assortment and random fertilisation produce variation in the genotypes of offspring.
- Compare spermatogenesis and oogenesis.
- Explain how errors in meiosis can lead to chromosomal abnormalities such as insertions, deletions, duplications, inversions, translocations and aneuploidy.
- Identify ploidy changes within a human karyotype to predict a genetic disorder.
- Explain the process of protein synthesis in terms of
  - transcription of a gene into messenger RNA in the nucleus
  - RNA processing (5’ cap, RNA splicing, poly-A tail)
  - translation of mRNA into an amino acid sequence at the ribosome, referring to transfer RNA, codons and anticodons.
- Determine the effect of point and frameshift mutations on polypeptides using the genetic code.
- Explain how gene expression is regulated in response to environmental signals and to allow for cell differentiation, including
  - chemical tags that affect chromatin structure (heterochromatin vs. euchromatin)
  - proteins that bind to the promoter region of a gene (transcription factors).
- Explain how genes from the HOX transcription factor family regulate morphology.
- Describe dominant, recessive, autosomal, sex-linked, polygenic and multiple-allele inheritance.

- Infer patterns of inheritance and predict frequencies of genotypes and phenotypes from genetic data, including
  - histograms (polygenic inheritance)
  - pedigrees (dominant/recessive, autosomal/sex-linked)
  - Punnett squares (dominant/recessive, autosomal/sex-linked and multiple-allele inheritance).
- Describe the process of making recombinant DNA, including the role of restriction enzymes, plasmids and DNA ligase.
- Describe how PCR and gel electrophoresis are used in DNA profiling and explain how differences in DNA allow for characteristic banding patterns.
- Interpret DNA profiles from gel electrophoresis.

### Science as a human endeavour

The following subject matter may be assessed in the internal assessments.

- Appreciate that
  - the Human Genome Project was an international, collaborative research project which resulted in the publication of the full sequence of the human genome in 2003. The databases associated with the project are freely available via the internet and used extensively by the international scientific community
  - full genome sequencing enables people to identify whether they have certain gene variants, which may enable doctors to structure individualised healthcare programs that will lead to better health; however, there is concern about the risks of making this data available, and the privacy issues regarding ownership and availability of the information
  - a wide range of transgenic crops are currently on the market, some having been engineered to resist pesticides, insects and disease; however, there is concern about the long term ecological impact of releasing engineered organisms into the environment, including the effects on non-target organisms, a speeding of the evolution of pesticide-resistant pest species, and the possibility of gene flow from crop species to weed species resulting in the emergence of 'super weeds'
  - our understanding of genetics and heredity has resulted from collaboration of people from a range of disciplines and continues to develop as new evidence comes to light. Examples of scientists who have advanced our knowledge in this field include
    - Emmanuelle Charpentier and Jennifer A Doudna — genome editing (CRISPR)
    - Elizabeth H Blackburn, Carol W Greider and Jack W Szostak — telomeres
    - Roger D Kornberg— transcription
    - Edward B Lewis, Christiane Nüsslein-Volhard and Eric F Wieschaus — HOX genes
    - Richard J Roberts and Phillip A Sharp — introns and exons.

### Science inquiry

The following subject matter may be assessed in the internal assessments.

- Extract DNA from strawberries, kiwifruit or wheat germ.
- Interpret DNA profiles from gel electrophoresis (laboratory work or computer simulation).
- Investigate
  - the safety and efficacy of gene technologies such as CRISPR and GM crops
  - how advances in our understanding of genetics/epigenetics are changing the way we prevent, diagnose and/or treat disease
  - applications of bioinformatics and/or data from the Human Genome Project.
- Explore how the work of different scientists has contributed to our understanding of genetics and heredity.

## Topic 2: Continuity of life on Earth (15 hours)

### Science understanding

The following subject matter can be assessed in the external assessment.

- Distinguish between microevolution and macroevolution.
- Explain microevolutionary change through the main processes of mutation, gene flow and genetic drift.
- Explain natural selection and identify the three main types of phenotypic selection: stabilising, directional and disruptive.
- Calculate allele frequencies from genotype data.
- Analyse data to determine the effect of a selection pressure on a population, recognising that selection for an allele can be positive or negative.
- Describe how macroevolutionary changes result from the accumulation of microevolutionary changes using examples of divergent, convergent, parallel and coevolution.
- Explain how geographic, temporal and spatial isolation influence gene flow and may lead to allopatric, sympatric and parapatric speciation.
- Explain why populations with reduced genetic diversity face increased risk of extinction.
- Explain how comparative genomics provides evidence for the theory of evolution and how conserved sequences can be used to date divergence.
- Infer species relatedness from cladograms, phylograms and molecular sequence data.
- Determine episodes of evolutionary radiation and mass extinctions from an evolutionary timescale of life on Earth (approximately 3.5 billion years).

### Science as a human endeavour

The following subject matter may be assessed in the internal assessments.

- Appreciate that
  - ICTs such as genetic databases and The Basic Local Alignment Search Tool (BLAST) have allowed large-scale mapping and analysis of DNA and protein sequences. Technological developments in the fields of comparative genomics, comparative biochemistry and bioinformatics have enabled identification of further evidence for evolutionary relationships
  - scientific theories are explanations of the natural world that have been repeatedly tested and corroborated in accordance with the scientific method. Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power. Contemporary evidence for evolution comes from palaeontology, biogeography, developmental biology, morphology and genetics.

### Science inquiry

The following subject matter may be assessed in the internal assessments.

- Analyse genotypic changes for a selective pressure in a gene pool (laboratory work or computer simulation).
- Investigate
  - how different selection pressures (e.g. human activities, changes in climate) are affecting evolution
  - how phylogenetic data is used to track and monitor viruses
  - the effectiveness of ‘green corridors’ in maintaining gene flow between populations
  - how data from palaeontology, biogeography, developmental biology, morphology and/or genetics is used to provide evidence for the theory of evolution
  - how genomic data is used to track human migration.