Earth and Environmental Science Module 5: Earth’s resources

## Table of contents

[Earth and Environmental Science Module 5: Earth’s resources 1](#_Toc44676335)

[Table of contents 2](#_Toc44676336)

[Teaching the Year 12 Modules 3](#_Toc44676337)

[Course overview 3](#_Toc44676338)

[Module summary 5](#_Toc44676339)

[Big ideas 5](#_Toc44676340)

[Relationship to other modules 6](#_Toc44676341)

[Core concepts 6](#_Toc44676342)

[Opportunities for extending concepts 7](#_Toc44676343)

[Alternative conceptions and misconceptions 8](#_Toc44676344)

[Suggested teaching strategies 9](#_Toc44676345)

[Appendices 11](#_Toc44676346)

[Appendix 1: Banded iron formations investigation 11](#_Toc44676347)

[Appendix 2: Annotated geological timescale 13](#_Toc44676348)

[Resources 19](#_Toc44676349)

## Teaching the Year 12 Modules

The new Stage 6 Earth and Environmental Science course was implemented in NSW schools in 2018-2019. This syllabus incorporates new content and learning activities such as Depth Studies. The syllabus is designed around inquiry questions and formal assessment tasks emphasise the skills for working scientifically.

The Year 12 course investigates how the processes of plate tectonics, the formation of water and the introduction of life interact with the atmosphere, hydrosphere, lithosphere and climate. Investigation of hazards, the mitigation of their effects and resource management are also considered which leads to an understanding of the need to centralise the theme of sustainability for the long term welfare of our planet and all forms of life dependent upon it.

Therefore, pedagogies that promote inquiry and deep learning should be employed in the Earth and Environmental Science classroom. The challenge presented by the additional content and the change in pedagogical approach were the catalysts for the preparation of these module guides for Stage 6. These guides are intended to assist teachers deliver Earth and Environmental Science effectively by outlining overarching concepts (big ideas), core and extended ideas, strategies for teaching the modules, uncovering of alternative conceptions, and strategies to address them. The guides support the teacher in facilitating the development of deep knowledge structures, such as the relationships between concepts. The module guides do not cover all aspects of the syllabus, as that was not within the scope of the project.

It is essential that teachers note that the module guides do not substitute the syllabus, but only support teachers to teach it. The information contained in these documents are correct at the time of publication. While every effort has been made to eliminate errors, any errors or omission that are identified after the release of these documents will be corrected and released as resource updates. It is recommended that teachers access the Curriculum website for the latest version of these documents.

### Course overview

During the teaching of the Year 11 course, it is expected that students have been provided opportunities to develop all seven of the Working Scientifically skills. Ideally, these would be embedded into the teaching of the Knowledge and Understanding components of the course. In preparation for the Year 12 course, students in Year 11 could benefit from work that engages them in the following areas:

* Propose hypotheses and design and conduct valid and reliable practical investigations that enable the collection and analysis of data. Teachers should look for opportunities to engage students in these beyond where the syllabus explicitly states the need to conduct a practical investigation.
* Construct and analyse graphical data (particularly line graphs) for both primary and secondary sources. This will be essential for an understanding of a changing Earth over time, including geological events and climate changes.
* Assess the uses, benefits and limitations of various types of scientific models. Many of the processes that occur on the Earth are invisible (such as convection currents beneath the surface) or happen very slowly (movement of tectonic plates, the process of evolution over geological time, for example). Models help people to better understand these types of processes.
* Determine the impacts of various technologies in improving the understanding of various concepts, including events that have occurred in the ancient past and potentially those that will occur in the future.
* Collect relevant information from secondary sources and determine the accuracy, reliability and validity. Many of the investigations will require students to obtain information from the Internet or other sources. Students will benefit from learning how to access the correct sort of information and appreciate how new evidence can change prevailing views about aspects of Earth and Environmental Science.
* Understand the major features of the Earth’s spheres and the relationships between each one. This is an underlying theme the spans both the Year 11 and Year 12 courses. It is essential that students understand the components of each one and can appreciate how changes in one can impact on the others.
* Develop skills in numerical scaling, with particular reference to periods of geological time. It is expected that students have developed a good understanding of the divisions of the geological timescale.
* Develop an understanding of relative and absolute dating of rocks and fossils. Using and constructing stratigraphic diagrams where appropriate and numeracy activities to build skills in applying radiometric dating principles.
* Construct simple diagrams of various processes, including tectonic boundary relationships and the geological and/or volcanic features associated with them, the formation of earthquakes at fault zones and the movement of warm and cool water in ocean currents across the Earth.
* Develop a deep understanding of the impacts of humans on the Earth and an appreciation of the importance of sustainability in its various forms. This includes understanding the roles of Aboriginal and Torres Strait Islander Peoples in caring for Country and Place.

The Year 12 course offers an insight into the various ways that the Earth has changed throughout its long history and will continue to change into the future. Some of these changes have occurred gradually over long periods of time and others have been much more rapid. They occur due to natural processes, such as the movement of tectonic plates and their associated geological events like volcanic eruptions, while others have done so due to human activities, such as the burning fossil fuels and the links to climate changes. Students will continue to develop a deep appreciation of the interrelationships between the geosphere, atmosphere, hydrosphere and biosphere in the past and present, as well as build positive views towards sustainability into the future.

### Module summary

This module explores the following inquiry questions:

* **IQ5-1:** How did today’s biosphere originate and develop?
* **IQ5-2:** How did the changes to the biosphere affect the Earth’s geosphere, atmosphere and hydrosphere?
* **IQ5-3:** What affect does the plate tectonic supercycle have on the Earth?
* **IQ5-4:** What is the role of fossils in expanding what is known of geological time and past life on Earth?

The Earth is dynamic. It has changed over the course of geological time and in many different ways. This module requires students to understand some of the processes and impacts of these major changes and to develop deep appreciation of the interactions between the geosphere, atmosphere, hydrosphere and biosphere. Students will develop their understanding of plate tectonics, fossils, climate cycles and evolution to help appreciate some of the major events that have occurred in the ancient past. This will allow them to build their scope of understanding the geological timescale, and to make predictions into the future.

### Big ideas

* The Earth is undergoing continuous change. Various processes are influencing these changes over various lengths of time. Tectonic movements, atmospheric compositions, the evolution of species and other significant events continue to shape the Earth.
* There is an interrelationship between changes in the geosphere, atmosphere, hydrosphere and biosphere; changes in one of these has impacts on the others.
* The ideas around the origins and development of early life on Earth are still debated by scientists. The impacts of the evolution of various species on the environment has been significant.
* Scientists have discovered palaeontological and geological evidence for the major events that have occurred in Earth’s history.
* The impacts of plate tectonics on global climate and the evolution of species has been significant.
* Fossils and other forms of evidence have been used to generate the geological timescale for scientists to better understand Earth’s history.

### Relationship to other modules

Many of the concepts covered in this module builds on presumed knowledge from the Year 11 course and of Stage 5 Science. Some suggested areas of focus to activate prior knowledge could include:

* The geological timescale, including its development using fossils and other evidences, and the major divisions (Module 1).
* Features of the geosphere, hydrosphere, atmosphere and biosphere (Module 1).
* The theory of evolution by natural selection. This will be important for students to appreciate how species have adapted to new environments, e.g. colonisation of the land (Stage 5).
* The theory of plate tectonics, with emphasis on plate boundary interactions and tectonic structures. This is essential for students to have an appreciation of the plate tectonic supercycle (Module 2).
* Relative and absolute dating techniques of rocks and fossils (Module 1).

For students who are also studying Biology, the need to emphasise the theory of evolution may be less important, however, all students need to appreciate that species have changed over time in response to selective pressures in their environment.

Some potential future links to other Modules in the Year 12 course could include:

* The effects of the plate tectonic supercycle (such as explosive volcanism) on the atmosphere and biosphere links with concepts in both Module 6: Hazards (volcanoes as geological disasters) and Module 7: Climate Science (how larger eruptions impact global climates).
* The process of dating rocks and fossils links with the concept of dating past climates using ice cores, dendrochronology, in Module 7.
* A deep understanding of the geological timescale is useful for appreciating aspects in Module 8: Resource Management, including discovery of non-renewable resources in rocks of certain age period, for example Carboniferous Period. It is also potentially relatable when studying ancient climate data in Module 7.
* When studying banded iron formations, it could provide a useful example that links to mining of non-renewable resources (that is, for steel production) in Module 8.
* The idea of the relationships between the spheres is something that appears throughout all modules.

### Core concepts

When exploring the inquiry questions within each module, the most important concepts that students need to develop a deep understanding of can be broken down. These include:

* The scientific debate around the origins of the organic molecules for life and the first cells. The various forms of scientific evidence that exists for these, and the influence of newer technologies on these ideas should be explored.
* The reasons and the evidence for the development of major forms of life (such as photosynthetic life, multicellular life, terrestrial life) through geological time. Students should investigate the geological and palaeontological evidence for these and some of the proposed reasons for them.
* Living things have impacts on their environment, including the geosphere (for example banded iron formations), atmosphere (for example ozone development) and hydrosphere (such as iron reacting with dissolved oxygen in ocean water, allowing deposition of banded iron formations). These, in turn, can have effects on the evolution of species (for example ozone allowed for the colonisation of the land by plants and animals).
* Plate tectonics has played an important role in influencing major Earth processes, including climate and the evolution of species. For example, the subduction of plates can lead to explosive volcanic eruptions that can influence global climates, and the movement of continents can separate and isolate species, influencing their evolution over time.
* Fossils and the fossil record have helped scientists understand the past. Dating of rocks and fossils and analysis of the fossil record has allowed for development of the geological timescale and for an understanding of past life and significant events, such as the Cambrian explosion and mass extinctions.

### Opportunities for extending concepts

These are some suggested pathways students could investigate to allow for a deeper appreciation of the inquiry questions within this module:

* Assess the evidence, comparing different scientific ideas regarding the origins of the first cells. Compare these with culturally based ideas about the origins of early life, including the perspective of [Aboriginal Peoples.](https://www.westernsydney.edu.au/campbelltown_observatory/home/areas_of_research_and_teaching/aboriginal_astronomy/origin_of_the_universe)
* Investigate the process of photosynthesis in modern day plants and relate this to the process in ancient cyanobacteria. Discuss some of the similarities and differences, including the way the process influences the atmosphere.
* Discuss the difference between prokaryotic and eukaryotic cells in reference to early forms of life. Explain the significance of the evolution of the first eukaryotic cells.
* Discuss the chemical reaction between iron and oxygen and the factors that can affect it. Relate this to the development of banded iron formations.
* Explore different scientific hypotheses to explain causes for the Cambrian explosion and/or the development of the Ediacaran fauna.
* Predict the effect of the plate tectonic supercycle on future climates and the evolution of species.
* Relate the plate tectonic supercycle to the existence of past supercontinents such as Pangaea and Rodinia.

### Alternative conceptions and misconceptions

* The title of the module itself is quite vague and could be misleading, giving the impression that the content focus is on typical geological processes such as plate tectonics. It is important that teachers explain that this module incorporates various processes beyond these, including atmospheric changes, evolution and the geological time scale, and fossil formation.
* When investigating the Urey and Miller’s experiment, teachers may need to emphasise that the findings support that organic molecules for life, such as amino acids, can form from inorganic ones, not that actual living cells form in this way.
* Students may think that individual organisms evolve or adapt to a changing environment. It is important that teachers emphasise that the species evolves in response to selective pressures in the environment.
* Students may have learnt about the existence of Pangaea as the only pre-existing supercontinent. But supercontinents have existed before Pangaea, as the plate tectonic supercycle is thought to have been through multiple cycles. This should be emphasised when teaching about the plate tectonic supercycle.
* The geological timescale is being constantly refined including the preferred names of time divisions. Teachers will need to consult the NESA website for the [current version.](https://www.educationstandards.nsw.edu.au/wps/wcm/connect/6d2a0cc8-fd8d-4279-93e7-ed6abb13e391/ess-geological-time-scale-hsc-exams-2019.pdf?MOD=AJPERES&CVID=) It may be necessary to remind students that several previous versions exist and that secondary sources may refer to lengths of time with unfamiliar names (for example Mississippian).
* The development of banded iron formations can be a very complex process to understand and what they indicate about events in the past can be misinterpreted. As this is an example that is listed in the syllabus and therefore optional, it does provide a future link to Module 8 and it is suggested therefore it is explicitly taught. The understanding of basic chemical reactions could be refined here. It is suggested that teachers assist students to construct flow-charts or other diagrams to help break down the major steps in their formation. There are some animations and videos available online (see resources). Linking their development visually to the geological timescale may also help.
* The concept of evolution is referred to at various times. It is expected that students have a fundamental understanding of evolution to appreciate the development of the biosphere through geological time. Teachers may need to spend some time revising the process of natural selection, perhaps even modelling the process, to allow students to better interpret reasons for major changes in the biosphere through time.
* Explaining the link between the principles of uniformitarianism and superposition and the occurrence of significant geological events could be challenging, with limited examples available. It would be important to reaffirm what these terms mean and to use basic stratigraphic diagrams to help students to understand them. Linking to significant events, such as large volcanic eruptions or the Cambrian explosion would be then be appropriate. While there is no mandated requirement to teach about mass extinction events here, it does provide a good opportunity to link with content other modules.

### Suggested teaching strategies

Teachers should have the flexibility to teach in whichever sequence suits them best, however, Module 5 is an ideal one with which to begin for the Year 12 course. This is because some of the big ideas that connect to other modules are introduced here.

The order in which the inquiry questions are taught should be flexible, however, it would be ideal to begin the course with IQ5-1. This way, the processes covered throughout the module can be taught in a somewhat chronological sequence that could be easier for students to comprehend. One strategy could be to teach the concepts with continual reference back to the geological timescale. For example, students could construct their version of a timescale early in the course, then add significant events to it as they are learnt, such as the origins of photosynthesis, conquest of land by plants and animals, formation of Pangaea and mass extinctions.

Some inquiry-based learning activities that could prompt practical investigations and address the Working Scientifically skills could include:

* Students develop their own inquiry questions on the origins of organic molecules and/or the first cells. This could involve accessing secondary sources such as articles in online newspapers, scientific websites or scientific journals. Students could assess the reliability, validity or accuracy of the information obtained.
* Students research and make predictions on what the significance of the discovery of black smoker communities have for understanding early life on Earth. They could assess the importance of technologies in furthering our understanding of the ancient past.
* Use scaling activities that require mathematical calculations to construct versions of the geological timescale to solve problems. These activities can build numeracy skills.
* Interpret graphical data on the composition of the atmosphere over time (such as analysing how and why oxygen concentrations have changed over time), then make predictions about possible future atmospheric compositions.
* Analyse the fossil record and link fossil discoveries to changes in ecosystems through geological time (such as Ediacaran and Cambrian Periods show significant changes in animal diversity).
* Calculate the relative and absolute ages of fossils using various dating techniques. These tasks can encourage more use of numeracy skills (use simple mathematical calculations). These can then be applied to significant geological events, for example mass extinctions and large volcanic eruptions.

These are some practical investigations that may help to encourage more use of the Working Scientifically skills:

* Investigate the reaction between iron nails and oxygen and the conditions under which the reaction occurs fastest in relation to the development of banded iron formations. This could be used to emphasise fair testing principles (it should be noted that this concept is not essential teaching as part of the course – see appendix).
* Model the plate tectonic supercycle. Students could design and create their own models (for example using playdough) that link changes in the cycle to climate variations and/or evolution using digital technologies such as Stop Motion. The strengths and limitations of models such as these could be evaluated.
* Students could create models of various types of fossils (for example moulds, casts) using plaster and chocolate and determine which model is the most effective in explaining the process of fossilisation.
* Students could investigate how an ecosystem is affected when plants and/or animals are introduced or removed. This could potentially be modelled in a closed jar system. Students could relate this to how the biosphere can impact the surrounding environment, for example the atmospheric composition.

## Appendices

### Appendix 1: Banded iron formations investigation

**Task outline:** This task allows students to use skills in interpretation of graphical data, make predictions and allow for follow-up secondary source research or first-hand investigations. It should be noted that in the syllabus, the specific concept of the role of oxygen in production of banded iron formations is only suggested as an example to be investigated for impacts of development of the biosphere on the other spheres.

**Background:** The earliest photosynthetic lifeforms to appear on the Earth were cyanobacteria. Many scientists predict that they appeared around 3.6 Ga (billion years ago). As a result of the photosynthetic process, they released oxygen gas into oceans as a waste product. The oxygen was able to react with iron particles in the oceans, which may have been supplied from the release of materials from deep ocean hydrothermal vents. The result is the formation of iron oxide, which would sink and be deposited on the ocean floor. These have formed many of the world’s iron ore deposits which continue to be mined in many parts of the world, including Australia. Indigenous Australians have also traditionally used iron oxide-rich rocks as a source of pigments for making ochre for body decoration, sun protection and art making.

The timescale below shows the periods in history during which the banded iron formations were deposited, as well as the changing concentrations of atmospheric and hydrospheric oxygen.

Image credit: NESA

Some possible questions/opportunities for discussion or investigation:

* Suggest reasons why values for oxygen levels are not supplied here
* Predict why oxygen levels increased in the hydrosphere and atmosphere in the way shown in the timeline
* Predict a possible consequence for the accumulation of atmospheric oxygen for other forms of life
* Construct a flow-chart that summarises the major processes that occurred in the development of banded iron formations over time
* Design a first-hand investigation into the factors affecting the reaction between iron and oxygen (for example via rusting of nails)
* Investigate using secondary sources the historical and current use of iron oxide by Aboriginal Australians

### Appendix 2: Annotated geological timescale

#### Comparison of life and climate during the Archean and Proterozoic Eon

Archean Eon

|  |  |  |
| --- | --- | --- |
| Era | Life  | Climate |
| Paleoarchean3600-3200 MA(million years ago) | Stromatolites and bacterial fossils from Paleoarchean rocks in the Pilbara craton of WA indicate bacteria start to form colonies | Higher than average surface temperatures today. Large amount of greenhouse gases that warm Earth’s atmosphere by absorbing infrared radiation. Atmosphere contains mostly greenhouse gases (methane, carbon dioxide, water vapour ammonia, nitrogen) |
| Mesoarchean3200-2800 MA | Stromatolites indicate bacterial colonies were present which contained photosynthetic cyanobacteria | Oxygen was being generated by photosynthetic cyanobacteria but little is present in the atmosphere. Greenhouse gases still dominate the atmosphere |
| Neoarchean2800-2500 MA | Stromatolites continue to be widespread and indicate photosynthetic cyanobacteria still the dominant form of life. Only other widespread forms of life were other bacteria and Archaea.  | Oxygen still being generated by photosynthetic bacteria during this era, very little in the atmosphere. Oxygen as a highly reactive gas was being consumed by chemical reactions in the oceans and atmosphere. Greenhouse gases still dominate the atmosphere. |

Proterozoic Eon

|  |  |  |
| --- | --- | --- |
| Era | Life  | Climate |
| Paleoproterozoic Era2500-1600 MA | Photosynthetic cyanobacteria dominated early in the era. Third domain of life, eukaryotes evolved as single-celled algae but when several joined together (colonial) this paved the way for modern plants, animal and fungi. Possible multicellular algae evolved in late Paleoproterozoic era. | Free oxygen began to accumulate in the atmosphere and caused the Great Oxidation. First series of glaciation began early in the Era.Due to cyanobacteria and algae diversity the first free oxygen enters the atmosphere. End of this era oxygen made up 1% of the atmosphere. This was only one twentieth of today’s level. |
| Neoproterozoic EraTonian period1000-850 MA | Single-celled green algae underwent the first major diversification during Tonian.There is some evidence of multicellular algae in rocks of this age. Although no fossil animals are known from Tonian rocks, there is some evidence of small worm-like animals.  | Concentration of oxygen in the atmosphere was approximately 2% and had not increased since the Mesoproterozoic Era |
| Neoproterozoic EraCryogenian period850-635 MA | Fossil amoebas, the oldest fossil of single-celled animals found in rocks from this period. | Two major ice ages during this period.In the second half of this period, climate was so cold, ice caps covered the entire surface of the Earth ‘Snowball Earth Hypothesis’. |
| Neoproterozoic EraEdiacaran period635-542 MA | Multicellular animals appeared in the oceans in the middle of the Ediacaran period and towards the end, first shelled animals appeared.Ediacaran Biota – jellyfish, worms, sponges. Pen-liked animals. | After the glaciation of the preceding period, conditions were warmer.Oxygen concentration in atmosphere increased to 8%. |

#### Comparing fauna and flora in the Phanerozoic

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Period | MA | Atmosphere | Fauna | Flora |
| Cambrian | 542 - 488.3 | 12% Oxygen Carbon Dioxide was 12 x today's level | * Trilobites
* Arthropods
* Brachiopods
* Molluscs
* Echinoderms
* Vertebrates
 | * Microbial Film (with algae, fungi and lichen) covered land near bodies of water
 |
| Ordovician | 488.3 - 443.7 | 13 % Oxygen Carbon Dioxide was 11 x today's level | * Explosion in marine animal diversity
	+ Trilobites
	+ Brachiopods
	+ Conodonts
	+ Graptolites
	+ Molluscs
	+ Echinoderms
* Sea stars, bryozoans and armoured jawless fish appear for the first time
* Sea scorpions appear with largest arthropods up to 2m long
 | * First land plants evolve- moss., liverwort-like plants that need water to reproduce
 |
| Silurian | 443.7 - 416 | 14% Oxygen Carbon Dioxide was l0 x today's level | * First appearance of:
	+ Coral reefs
	+ Jawed fish
	+ Ammonoids
	+ Oldest known leech
* Abundant and diverse:
	+ Brachiopods
	+ Bryozoans
	+ Molluscs
	+ Trilobites
	+ Graptolites
* Animals inhabit the land:
	+ Millipede-like animals
	+ Centipedes
	+ Trigonotarbids (spider-like animals)
 | * Water dependent plants (mosses) lived near streams and lakes
* End of the period 1m tall vascular plants called Lycophytes were widespread
 |
| Devonian | 416 - 359.2 | 15% Oxygen Carbon Dioxide was 6x today's level | * First appearance of lungfish, sharks, amphibians and insects
* Mass extinction event affected marine animals and primary reef-builders caused by changes in global weather and erosion patterns resulting from the rapid diversification of land plants. Water run-off into the sea had dramatic effects on the ocean's chemistry and many marine species became extinct
 | * Colonisation of land plant sand diversification at the periods start was dramatic
* End of Devonian saw forests abounded, with some lycophytes and horsetails being the size of modern trees and reach 30 m high
 |
| Carboniferous | 359.2 - 299 | >30% 0xygen - dramatic increase | * Evolution of amniotic egg- ancestors of reptiles, birds and mammals were not dependent on water for reproduction
* Land dwelling arthropods increased in diversity
* Relatives of dragonflies with wing spans up to 75 cm and millipede-like arthropods long as 1.5 m
* Fish including sharks, increased in diversity
* Marine environments dominated by hard shelled brachiopods, bryozoans, molluscs and echinoderms
 | * Land plants such as ferns, seed-ferns and horsetails became prevalent during period
* Later in the period first conifers evolved
* Extremely high levels of oxygen combined with the presence of large forests let to first wildfires
 |
| Permian | 299-251 | Oxygen peaked at 35% (highest concentration in Earth's history) Levels drop by end of the period (half) | * First appearance of beetles and ammonites
* Diversification of reptiles and mammal-like reptiles
* First archosaurs (ancestors to dinosaurs, birds and crocodiles) appear later in period
* In the ocean, hard-shelled marine animals thrive (brachiopods, molluscs, echinoderms etc.) until end of the period. The 3rd of Earth' s big 5 mass -extinction events occurred, almost wiping out some of these groups (end of trilobites, sea scorpions and rugose coral)
 | * Ginkgoes and cycads first appeared and conifers diverse
* Due to extinction event Glossopteris flora disappeared and several other major groups of plants were almost wiped out
 |
| Triassic | 251-199.6 | Oxygen dropped to 15% | * Little diversity of fauna due to previous mass extinction
* Organisms recovered and new groups appeared and diversified
* First dinosaurs, marine reptiles, mammals, turtles, crocodiles and modern corals evolved
 | * Dicroidium flora flourished
* Conifers, cycads and ginkgoes flourished
* In the ocean dinoflagellates a type of algae which bloom to form red tides evolved
 |
| Jurassic | 199.6 - 145.5 | Oxygen made up to 21% of atmosphere but at the end of the period increased to 26%Carbon Dioxide was 4x today's level | * Dinosaurs grown to large sizes - perhaps due to high levels of oxygen in the atmosphere
* Predators increased in size
* Feathers first evolved- small predatory dinosaurs had feathers
* Later in period some small dinosaurs developed ability to fly and in doing so became birds
* Oceans invertebrate fauna was dominated by molluscs, echinoderms and corals
* Marine vertebrate fauna was dominated by fish, marine reptiles and large oceanic crocodiles
 | * Conifers reached maximum diversity and dominated the forests
* Tree-ferns appeared for the first time
 |
| Cretaceous | 145.5 - 65.5 | Oxygen made up to 27% of atmosphere but at the end of the period increased to 30% | * Dinosaurs at most diverse and dominated the landscape but declined later in the period
* Small and mainly nocturnal mammals become more common
* Insects diversified with first ants, bees, butterflies, termites, aphids and grasshoppers
* First snakes evolved from lizards
* Oldest fossils of monotremes and Marsupials appear in cretaceous rocks
* In oceans marine reptiles existed as well as hard-shelled ammonites, squid like belemnites, molluscs, sea lilies and sea urchins
* Rays, sharks and other fish diversified
* Mass extinction wipe 75% species of all plants and animals
 | * Flowering plants appear for first time in Early period
* End of period figs, magnolias, plane-trees and grasses evolved
* Evolution of flowering plants closely linked with pollinating insects, such as bees (co-evolution)
* Conifers, cycads, and ferns thrived in this period
 |

## Resources

* Heffernan, D. and Mahon, R. (2019). Spotlight NSW Earth and Environmental Science: Modules 5 to 8. Science Press: Alexandria - this book is currently one of the few that has been written specifically for the NSW syllabus. Teachers should appreciate the use of local examples but also be aware of limitations in regard to addressing Working Scientifically skills and perhaps too much detail with regards to content.
* [An introduction to Geology - online textbook](http://opengeology.org/textbook/) by Salt Lake Community College on An Introduction to Geology – a free online resource with basic concepts of geology that could be very useful for various sections of the course, including geological time, Earth’s history and plate tectonics.
* [Posters on Australia’s Evolution through Time](https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/71079) by Geoscience Australia – this provides a download link for free posters that chart the history of Australia from a geological perspective. They can be used to explore the evolution of life, palaeogeography, sea levels, climate change and some of Australia’s great mineral deposits. These are ideas that span across all modules.
* [Aboriginal perspectives on Creation](http://www.workingwithindigenousaustralians.info/content/Culture_2_The_Dreaming.html) by Working with Indigenous Australians – this provides information on aspects of Dreaming and provides some ideas around Creation of life. There are also links to other cultural perspectives and links to some further reading.
* An [interactive look into the major events in the development of the biosphere](https://www.paleozoo.com.au/origins.php) by Paleozoo - this program could be used as a starting point to activate prior learning for the topic. Contains several videos.
* [Video on Urey and Miller experiment](https://www.statedclearly.com/videos/what-was-the-miller-urey-experiment/) (duration 3:00) by Stated Clearly – this clearly describes the historical theories and developments that led to the Urey-Miller experiment. It emphasises the importance of appreciating the aim of the experiment. Further discussion may be needed on the development of understanding of the atmosphere of the early Earth and updated reproductions of the experiment.
* [Huge fossil discovery made in China's Hubei province](https://www.bbc.co.uk/news/world-asia-china-47667880) article by BBC Science - this source provides recent information on a new discovery that formed part of the Cambrian fauna assemblage. Students can extrapolate information from fossils to provide information on the evolution of Cambrian fauna. This gives information on new body structures, including not-so-hard-bodied organisms, showing that evolution of these fauna may not have been as rapid as first predicted.
* Video of [A Spacetime Odyssey Ep. 9](https://play.google.com/store/tv/show?id=MNgYr1F6iOU&cdid=tvseason-se8i3jQvhn5z12AIvCGOvQ&gdid=tvepisode-fjhxIMHzJ2Q) “The Lost Worlds of Planet Earth” by Cosmos – this explores the development of Palaeozoic life, mass extinctions, evolution influenced by the plate tectonic supercycle and the principles of uniformitarianism and superposition. There are also some links to concepts in Module 7 and Module 8.