A Resource Booklet for SACE Stage 1 Earth and Environmental Science

The following pages have been prepared by practicing teachers of SACE Earth and Environmental Science. The six Chapters are aligned with the six topics described in the SACE Stage 1 subject outline. They aim to provide an additional source of contexts and ideas to help teachers plan to teach this subject.

For further information, including the general and assessment requirements of the course see: https://www.sace.sa.edu.au/web/earth-and-environmental-science/stage-1/planning-to-teach/subject-outline

A Note for Teachers
The resources in this booklet are not intended for 'publication'. They are 'drafts' that have been developed by teachers for teachers. They can be freely used for educational purposes, including course design, topic and lesson planning. Each Chapter is a living document, intended for continuous improvement in the future. Teachers of Earth and Environmental Science are invited to provide feedback, particularly suggestions of new contexts, field-work and practical investigations that have been found to work well with students. Your suggestions for improvement would be greatly appreciated and should be directed to our project coordinator:: lenaltman9@gmail.com

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SOUTH AUSTRALIA

Government of South Australia
Department for Energy and Mining

GEOLOGICAL SOCIETY OF AUSTRALIA

TESEP

Evidence indicates that life first appeared on Earth approximately 3.7 billion years ago.

Prokaryotes were the first life on Earth.

The Archaeon Eon is the first time Earth had cooled enough to allow rocks and continents to form.

Prokaryotes are the earliest, simplest forms of life to exist. They do not contain complex organelles such as mitochondria or chloroplast. Their genetic material is not protected by a nuclear membrane, rather it sits in the cytoplasm.

Evidence indicates that first life on Earth occurred approximately 3.8 billion years ago as single celled prokaryotic bacteria, likely found in the ocean. Some of the earliest micro fossil evidence suggest organisms formed stromatolites from 3.5 billion years ago in the Archaeon Eon.

Stromatolites are calcareous mounds made of layers of photosynthetic cyanobacteria and trapped sediment. These provide evidence of the earliest known fossils. Stromatolites still form today.

With the appearance of prokaryotes in a carbon dioxide rich atmosphere, they thrived and via photosynthesis, consumed carbon dioxide and released oxygen.

First life on earth are the highly successful *cyanobacteria* which developed oxygenic photosynthesis. As a result, about 2.5 billion years ago, oxygen levels in the atmosphere began to rise, known as the Great Oxygenation event. This oxygen influx did not immediately benefit life. Oxygen intolerant microbes which dominated Earth went extinct. This caused a drastic reduction of the greenhouse gas methane from entering the atmosphere through oxidation and lead to the longest ice age known 'Snowball Earth'. Volcanic activity put enough carbon dioxide back into the atmosphere to warm the planet and allow aerobic life to flourish.

what is the photosynthesis equation?

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Why was the appearance of prokaryotes so influential on the evolution of life?

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Suggest how stromatolites have such an impact on the atmosphere.

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Explain how the anaerobic microbes went extinct, in the presence of the photosynthetic cyanobacteria.

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The Evolution of Eukaryotes

Called eukaryotes because their cells contain a membrane bound nucleus (Eu = true, Karyon = nucleus).

Eukaryotes are more complex organisms. They are the basis of all multicellular organisms. Through endosymbiosis, eukaryotes engulfed the larger organelles mitochondria and chloroplast. It is believed this is the beginning of their complex structure. This is evident in the independence the two organelles still maintain separate to the rest of the eukaryotic cell. They both contain their own genetic material and divide separately to the rest of the cell.

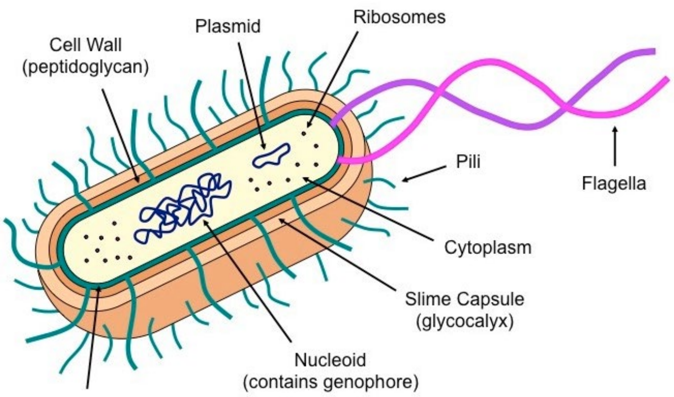

Figure 6.1: Prokaryotic Cell
Resource: http://www.ib.bioninja.com.au/standard-level/topic-1-cell-biology/12-ultrastructure-of-cells/prokaryotic-cells.html

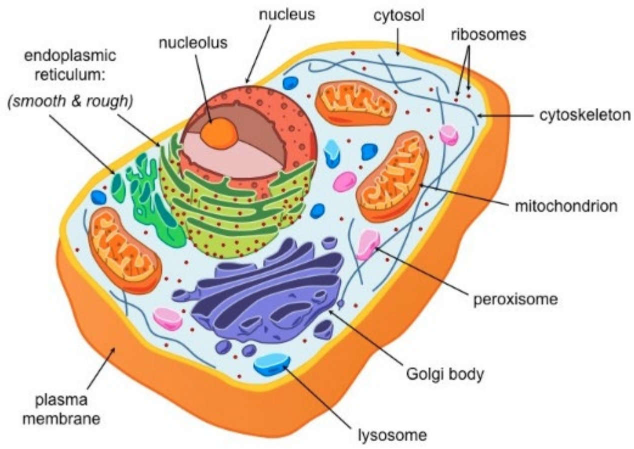

Figure 6.2: Eukaryotic Animal Cell
Resource: http://www.ib.bioninja.com.au/standard-level/topic-1-cell-biology/12-ultrastructure-of-cells/eukaryotic-cells.html

Eukaryotes can be multicellular **and** unicellular. Zooplankton or algae, for example, are unicellular eukaryotes.

Eukaryotes can be divided into four distinct kingdoms:

- **Protista –** unicellular organisms or unspecialised multicellular organisms
- **Fungi** - Chitin based cell wall, heterotrophs.
- **Plantae** – cell wall of cellulose and obtain nutrition via photosynthesis
- **Animalia** – multicellular organisms which obtain organisms via heterotrophic ingestion.

Ediacaran fauna, or animals of the specific part of geological time existed approximately 600 million years ago, found on six continents (excluding Antarctica). These fossils are the oldest known examples of complex, multicellular life on Earth. The Ediacaran period ended with the explosion of animal life in the Cambrian, represented by animals with skeletons and shells.

Specifically, one important location includes the Flinders Ranges in South Australia.

In the South Australian Flinders Ranges, the fauna suggests the presence of a shallow water ecosystem. The soft-bodied Ediacaran creatures lived on shallow sea floors. Upon death, they were smothered in sand and pressure. They were preserved as "death-mask imprints" or moulds of bodies that were in sandstone.

Whilst other significant finds include Russia, and Canada, Ediacaran fossils were named from the site where the fossils significance was first recognised.

Whilst the fauna has world-wide distribution, as with all animals, significant differences occurred due to location and environment.

South Australian Ediacara Fossils:

Resource: http://www.abc.net.au/science/photos/2014/10/22/4109389.htm?xml=4109389.mediarss.xml#bigpicturepos

Figure 6.1.3: Charmiodiscus arboreus may have been a soft coral with polyps arranged along its branches. Such frond fossils are very rare, probably because they were torn off by the storms that smothered these Ediacara seafloor communities with sand (Jim Gehling)

Figure 6.1.4: Dickinsonia Tenuis is related to the species that put reg Sprigg on the map. It was a flexible, segmented mat-shaped animal. The related Dickinsonia rex can be the size of a bathmat (Jim Gehling)

First Life – David Attenborough

Rachael Griffiths - Earth and Environmental Science – Biosphere

First Life (2010) BBC Television series – Sir David Attenborough visited National Heritage Listed Ediacara at Nilpena in the Flinders Ranges. There are two episodes at one hour each.

Explain the similarities and differences between prokaryotic and eukaryotic cells.

Similarities	Differences

Discuss possible benefits for eukaryotic cells which, through endosymbiosis, engulfed mitochondria and chloroplasts.

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Laboratory experimentation has informed theories about how life emerged.

Experiments can replicate primeval conditions to explain how life began.

Scientists have long attempted to recreate past climates in order to further their understanding of Earth's complex history. In their attempts to recreate past climates, understanding how and why Earth has changed improves our knowledge of what could come.

The Miller-Urey experiment, from the 1950's, was one of the most significant climate experiments performed. This chemical experiment was the reason for one of the biggest breakthroughs in the theories of the Origins of Life.

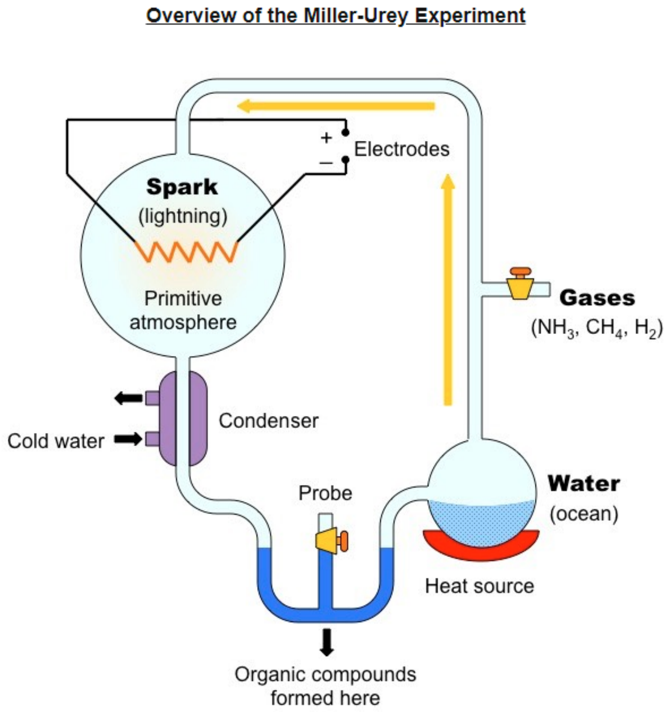

Image: http://ib.bioninja.com.au/standard-level/topic-1-cell-biology/15-the-origin-of-cells/non-living-synthesis.html

The purpose of the experiment was to design an apparatus which held gasses similar to those found in Earth's early atmosphere and sit these gasses over water, representing Earth's early ocean. The represented gasses include the hydrogen-based greenhouse gasses hydrogen (H_2), ammonia (NH_3) and methane (CH_4).

Electrodes were used to mimic lightning, focussed into the gaseous chamber and heat was applied to the water to mimic the extreme temperatures.

Over a week, the liquid was analysed, and it was found that through the inorganic compounds originally in the 'atmosphere', organic amino acid-based compounds were formed. These amino acid compounds include 13 of the 22 amino acids required to make proteins in cells.

The most fascinating and crucial results that came from the Miller-Urey experiment was the spontaneous creation of organic molecules and some of the first evidence that RNA (ribonucleic acid) was the first self-replicating life.

Most chemical reactions require energy and the Miller-Urey experiment showed the ultraviolet (UV) light from the sun and lightning can cause smaller molecules to link and create larger ones. The experiment supported the theory that a nitrogen-based atmosphere in these conditions can produce new chemicals.

Atmospheric and oceanic conditions in the Archaean Eon.

The Miller-Urey experiment was performed under the assumption that Earth was in an extreme hothouse event. The assumption was that, by just completing the Hadean Eon, where Earth was a ball of magma, the atmosphere must have been carbon dioxide rich and high in greenhouse gases. As a new atmosphere, there was no ozone, or protective layer around Earth. There was no protection from the UV radiation and as such, the environment allowed UV radiation in unobstructed providing mass amounts of energy.

In primeval Earth, there must have been an absence of oxygen and nitrogen as oxygen would destroy organic material (oxidation). The atmosphere must be hydrogen based (CH_4, NH_3, H_2) and moved into an oxygen-based atmosphere (CO_2, H_2O). There has been suggestion that earths earliest atmosphere has been derived from various sources, but consensus is that the atmosphere was toxic. Suggestion is that, because of its extreme gravity, (molecules are stuck within gravity and cannot leave the atmosphere), Jupiter's current environment is likely an example of Earth's first atmosphere.

The greenhouse gas-based atmosphere could well have been a key reason liquid water appeared on Earth at all. Given earth's unique position from the sun, allowing water to last in states of gas, solid and liquid, and the amount of activity that occurred. As a newly formed ocean, there was no life or supporting minerals or oxygen access. Oxygen appears in the ocean later through photosynthetic bacteria and millions of hydrothermal vents on the ocean floor.

1. Why was the Miller-Urey experiment so crucial to our understanding of first life on Earth?

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2. Explain why the atmosphere was nitrogen based.

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3. Suggest what could have occurred should a protective layer similar to today's ozone had surrounded Earth's atmosphere.

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4. Suggest why scientists should replicate the experiment, replacing the hydrogen-based gasses for nitrogen based. What could be achieved by changing this variable?

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Task: Research evidence of the Origins of Life on earth. List two other theories of how life first appeared on Earth and compare them and their likelihood to the Miller-Urey results.

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In any one location, the characteristics and interactions of the hydrosphere, geosphere, atmosphere and biosphere give rise to unique and dynamic communities.

Biotic and Abiotic Factors:

An ecosystem is a community of organisms of different species which interact with each other and the physical environment around them. An ecosystem can refer to a 'global' community where every single species interacts with all environmental features, or specific, such as a rainforest or coral reef ecosystem.

- Biotic features are **living** organisms. These include bacteria, decomposers and producers and consumers.
- Abiotic features are non-living factors that impact the environment. This includes, and is not limited to, water access, pH of soil, sunlight availability and climate.

Activity:

Consider a tropical rainforest. With its warm temperatures, humid climate and variety of biotic organisms living together.

1. List four biotic and four abiotic factors affecting this ecosystem.

Biotic	Abiotic

2. Explain why living things would be so reliant on abiotic factors. Use one of the above abiotic factors to explain your reasoning.

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3. Explain, using the rainforest example, the outcome of increased soil pH on the ecosystem.

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4. Suggest one way in which humans are impacting the rainforests. Suggest how our impact affects the abiotic environment and what that could mean for biotic organisms.

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Choose another ecosystem and in pairs or individually, consider the same questions.

Ecosystem: ____

What is the natural environment of this ecosystem? ______________________________

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1. List four biotic and four abiotic factors affecting this ecosystem.

Biotic	Abiotic

2. Explain why living things would be so reliant on abiotic factors. Use one of the above abiotic factors to explain your reasoning.

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3. Explain, using the rainforest example, the outcome of increased soil pH on the ecosystem.

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Changes in the geosphere, hydrosphere, atmosphere and geosphere give rise to new environments.

The four spheres, geosphere, hydrosphere, atmosphere and geosphere work together in a delicate balance. Should changes occur to one sphere, chain reactions occur within the others.

Should changes occur, the environment could no longer support the current biota within. Given the biotic organisms rely on their environment to survive, drastic changes could lead to species extinction and few species to thrive.

<u>Environment: The Sahara Desert</u>

The Sahara Desert was once a vast rainforest. Only 11,000 years ago, the Sahara was covered in lakes, rivers, grasslands and forests. This type of environment required a healthy, active hydrosphere, especially considering the atmosphere, due to Earth's axis. The angle solar radiation hits the Sahara cause long windows of humidity and aridity.

The Sahara region was once inundated with regular rainfall and thus had an abundant, complex ecosystem.

Due to excessive humidity and increased temperatures, the water dried up. With grasslands drying out, atmospheric moisture decreased. With lack of water and producers drying out, consumers quickly ran out of food and water. Evidence suggests this happened rapidly. Those animals who were able to adapt survived, those who did not are now extinct or no longer found in this region.

Today, the Sahara Desert is void of almost all life. There are species which still live there, such as the critically endangered Addax antelope, the Sand viper and the Deathstalker scorpion.

Image: https://www.livescience.com/55277-addax.html

Image: https://www.worldatlas.com/articles/what-animals-live-in-the-sahara-desert.html

Image: https://wildlife-facts.weebly.com/deathstalker-scorpion.html

Explain the change that occurred in the abiotic environment and how it impacted the biotic species. Why did the whole ecosystem change?

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<u>Environment: Coral Reef</u>

Coral reefs are considered the most diverse ecosystems in the world, and globally home approximately 25% of ocean life. They are considered 'living ecosystem' because the coral itself is made of many species of polyps, which secrete calcium carbonate. This calcium carbonate $CaCO_3$ is the reason coral reefs form and grow. In a healthy ocean with a slightly basic pH of 8.2, plenty of sunlight (for surface coral reef systems such as the Great Barrier Reef) for photosynthetic zooxanthellae, the coral thrives, supporting life and indicating a healthy ocean.

The abiotic factors which support a healthy coral reef include:

- Sunlight: zooxanthellae (algae) photosynthesise and produce oxygen.
- Warm water temperature: most reefs are found in the tropics (temperatures of 20-32°C)
- Clean water: allows sunlight through. Sediment can cloud water and cause seaweed to grow, impacting the reef.
- Saltwater: corals require salt water to survive. They will not be found near fresh water.

The different environment formed when climate change occurs is one of death and environmental destruction. Coral reefs are extremely vulnerable to any change in the abiotic environment and are early indicators of an 'unhealthy' ocean.

Increased use of greenhouse gasses is warming the atmosphere which in turn warms the ocean. Ocean warming, or ocean acidification, where pH becomes slightly more acidic causes coral bleaching.

Corals naturally do not have colour. The colour comes from the zooxanthellae which live within. Coral bleaching occurs because due to stress or pollution, the coral polyps remove the algae. By doing this the coral dies. If the producer dies, the food chain collapses.

Explain the change that occurred in the abiotic environment and how it impacted the biotic species. Why did the whole ecosystem change?

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Identify, measure and record the appropriate characteristics in a field location.

Field Trip Environment: Beach

Task: to observe, measure, identify and record the natural environment.

Hypothesis: ____

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Materials: ____

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Observations:

Biotic	Abiotic

Write your observations here. Include observations of natural and manmade influences to the environment.

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Results:

Time	Water Temperature	Air Temperature	Organisms Quantity	UV Index

Graph:

Discussion:

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Explain the changes to the ecosystem over the course of the day.

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Explain the influence of the atmosphere on the current ecosystem.

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Identify the most abundant organism. ____

Suggest changes to the ecosystem should that organism overpopulate.

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Explain possible changes to the ecosystem should water temperature rise. __________

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Environmental changes affect the distribution and abundance of organisms.

TED Talk: "How Can We Make Crops Survive Without Water?"
https://www.youtube.com/watch?v=2NWpMqD8Qyk

Explain the message of the TED talk and discuss the effects of the abiotic environments on our food supply. Discuss reasons why Jill Farrant suggests specific plant species and how they could help us survive our overpopulation in a drying, arid world.

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The characteristics of past environments and communities can be inferred from the sequence and internal textures of sedimentary rocks, and from enclosed fossils and trace fossils.

How fossils form:

There are various ways for fossils to form.

Most fossils form in a watery environment where, upon death, the plant/animal is covered in mud and silt. Soft tissue such as organs are not fossilized. When covered in mud and silt the bone/shells over time will be hardened into rock. As the bone decays, 'petrification' occurs and minerals seep into the cast, replacing the organic minerals.

In a **mold,** bone could decay completely leaving behind only a cast. This void could be filled with minerals and a stone replica, or **cast** is left behind.

Another method of fossilization is when insects/bugs become trapped in tree sap. Upon death their whole bodies are preserved as the tree sap hardens into amber.

Finally, fossilization can occur due to volcanic eruption. When Mount Vesuvius erupted in 79AD, white, then dark grey pumice rained down on Pompeii like hail. Whilst death was likely due to the extreme heat from the pyroclastic flow or suffocation, preservation occurred when several metres worth of ash, pumice and debris covered the victims.

Living animals and environments can be compared to similar fossils.

Comparing past environments such as roots, soils and stream deposits by studying rocks allows us to investigate a past environment and make sense of what

used to be. Once basic information is obtained, it can be compared to that of a modern environment.

Image: https://www.news.com.au/technology/science/animals/the-sea-that-could-engulf-australia/news-story/c7000a780feb1666fa7382b65464c2c8

How do we know Australia used to be underwater?

One hundred million years ago, the middle of Australia was almost completely covered in water – a prehistoric sea called the *Eromanga Sea* full of marine life.

This sea and its life likely died out with the asteroid of 64 million years ago which covered the sky in dirt gas and toxic fumes and killed most life on Earth.

Thousands of pristine fossils, some of which have turned to opal, of marine reptiles such as ichthyosaurs, turtles, ammonites, belemnites and shells have been found and the only explanation for their presence is a sea.

The way beds face can be determined by the formation of sedimentary structures.

Rocks accumulate in layers in environments including ocean floor, deserts and rainforests. Over time the sediment consolidates to become rock strata or layers. The lowest layers are older and contain minerals formed at the time of deposition as well as fossils.

The Principle of Superposition: a series of stratified sedimentary rock; the lowest stratum being the oldest.

The Principle of Superposition determines the order in time that fossils are found in rock layers. The fossils can be used to date the rocks through biostratigraphy. This helps indicate when each layer was deposited and thus adds to the Geological Timescale.

Superposition does not apply when the rocks have been impacted by magma intrusion, folding or faulting.

Sedimentary structures provide information about specific processes within depositional environments. The individual beds or lamination can help to discover the conditions of the environment at the time.

Graded bedding: occurs when turbid currents carrying sediment suddenly drop speed, depositing the sediment. In these conditions the larger, heavier deposits settle first, followed by the lighter, grainier sediment on top.

Graded Bedding Resource: https://www.nr.gov.nl.ca/mines&en/geosurvey/education/features/structur

Cross-bedding: This usually occurs where sediment is constantly moved by wind or water and the grains eventually build up into piles of sediment.

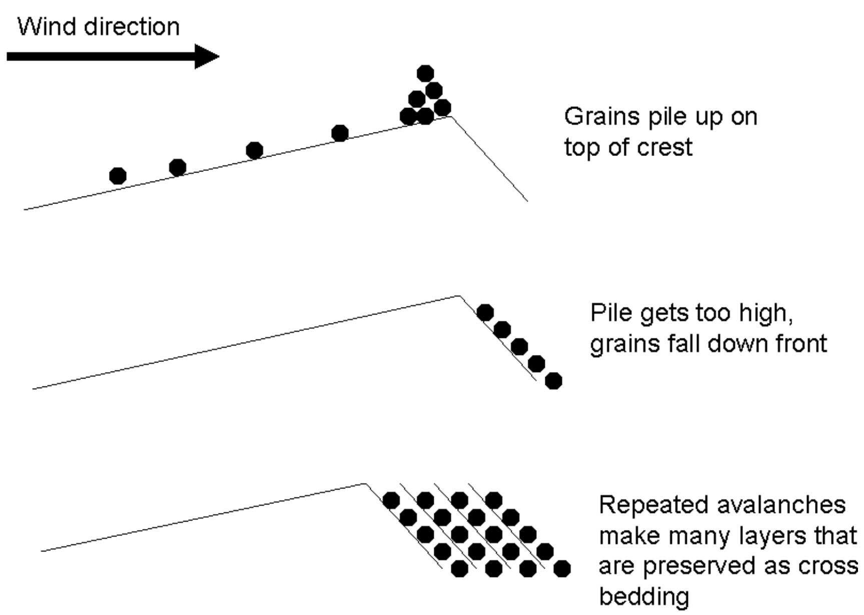
Deposition occurs when sediment fells down and builds up layers usually within ripples. The cross bed refers to the visible layers of sediment within the ripple marks. The down current slope of a dune or sand wave depositing fragments of sediments which are then eroded later. Deposition of new sediment is constant.

Cross-Bedding Resource: https://www.nr.gov.nl.ca/mines&en/geosurvey/education/features/structures/

View: https://walrus.wr.usgs.gov/seds/bedforms/animation.html

When cross beds form, the grains avalanche down the face. This leaves a 'tail' which lays on top of the bottom bedding surface. The top is of these features is usually eroded away.

Sand deposited by avalanching down the slope can become packed with water. *Shearing* and erosion by a one-directional current of wind or water when part of the rock breaks off and falls, ultimately facing a different direction to the rest of the rock.



Cross bedding: https://serc.carleton.edu/NAGTWorkshops/sedimentary/images/cross_bedding.html

Ripple Marks: usually formed by air or water.

As the grains move with the wind or water, eventually sediments start piling up on top of each other until they form a ripple structure.

There are two forms; symmetric (wave formed) or asymmetric (current formed). They form on the top of a bed. When new layers build, ripples are preserved.

Symmetric, or wave formed come from an oscillating motion - a back and forth motion of water. Symmetric ripples are quite often found in beaches with the surface water coming up onto land, then moving back toward the ocean.

Asymmetric or current ripples are caused by wind or water moving back and forth asymmetrically. The grains show the water is always moving up the ripple, so the longer, smoother side shows direction. The shorter side of an asymmetric ripple has a build up of sediment falling as the water passes over.
Another example is sand dunes, which oven have a longer side, followed by a sudden ending. These dunes show the regular movement of the wind. Because of the ripples the direction of the current at the time can be determined as the longer sides face upstream.

Symmetrical, wave formed ripples: https://www.nr.gov.nl.ca/mines&en/geosurvey/education/features/structures/

Asymmetrical ripple marks: https://www.nr.gov.nl.ca/mines&en/geosurvey/education/features/structures/

Further Research/Background Information:

YouTube: DCC – Geology Online: Physical Geology: sedimentary

Questions

1. State the Principle of Superposition

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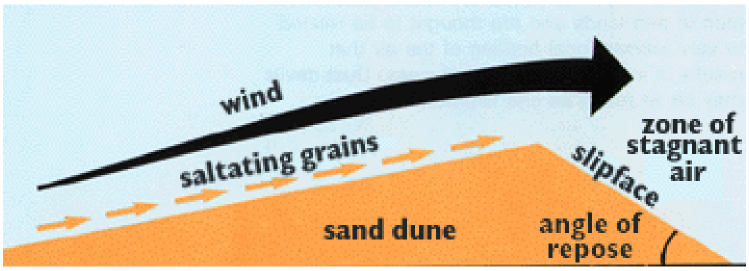
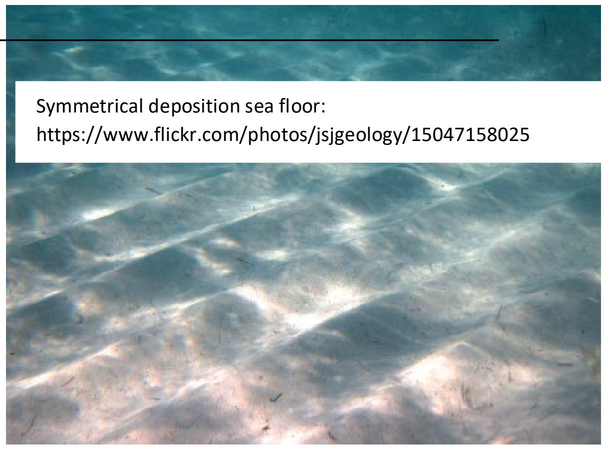


Asymmetrical sand dune formation: https://www.earthonlinemedia.com/ebooks/tpe_3e/eolian_systems/dunes.html



Symmetrical deposition sea floor: https://www.flickr.com/photos/jsjgeology/15047158025

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2. Explain with the aid of diagrams, why it is very important for a geologist trying to determine the geological history of an area, to decide whether or not a series of rocks has been overturned.

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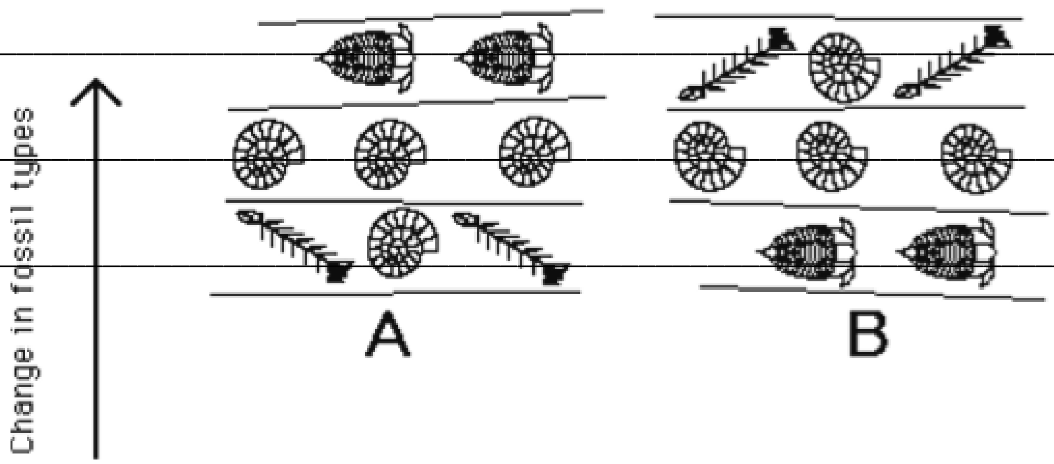
3. State, giving a reason, which rock sequence shown has been overturned.



4. List characteristics that must be possessed by index fossils.

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5. Suggest why ripple marks could aid palaeontologists to locate full remains of fossils.

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The diversification and proliferation of living organisms over time and the catastrophic collapse of ecosystems can be inferred from the fossil record.

The Fossil Record and the Geological Time Scale:

Significant changes to the geological timescale seem to coincide with mass extinction events or events of significant ecosystem fluctuation. Fossils are fundamental to the geological time scale as they assist with understanding of when climates changed and understanding of when and how evolution occurred.

Most eons/eras end in ‘zoic’ which recognises the presence of animal life.

> The Proterozoic Eon contains fossils of simple organisms such as bacteria.
>
> The Phanerozoic Eon contains fossils of complex organisms such as dinosaurs and trees.

Index fossils:

Index fossils can tell exactly one specific point in geologic time. These fossils must be distinctive, abundant, easily recognisable and be widespread and found across a large geographic area in a limited window of geological time.

The most successful organisms became abundant, becoming widespread and in large quantities. At the same time, they are the most vulnerable to environmental change and therefore, extinction. Their time on Earth was short but they thrived, making them ideal index fossils. Major index fossils are marine organisms, though some land organisms are useful.

The incomplete fossil record and the 600-million-year-old gaps.

Not all living things come with a hard shell or bone that can be fossilized. Because of this lots of invertebrates, cartilaginous animals and bacteria have left no trace of their existence. Most of our knowledge and understanding of the past comes from fossils and the Earth itself, rocks and ice cores indicating climates of the past.

Prior to 600 million years ago, there was no complex life on Earth. Finding fossils of living organisms of the time is more unlikely and evidence of life that is found does not provide many details. Not all living things come with a hard shell or bone that can be fossilized. Because of this lots of simple organisms lived and died without leaving a trace.

Fossils indicate past environments in the geological time scale.

Studying the fossil record, or palaeontology, is understanding how ancient organisms lived and the environment they lived in. The structures and size can indicate whether they were dominant species and whether the environment was oxygen rich.

The fossil record shows us traces of the first bacterial life on Earth, in the Western Australian stromatolites. It shows us the boom of complex life in the Cambrian period and shows us how life evolved during the Jurassic to the Cretaceous, showing us mammalian ancestors.

Fossils allow us to reconstruct ancient environments by studying roots, soil horizons and stream deposits – comparing them with current environments.

<u>Euromanga Sea</u>

Such as with the Eromanga sea which used to cover Australia, the presence of large numbers of marine organisms suggests the presence of a sea. Comparing prehistoric turtles to those alive today can indicate how they have evolved over millions of years. Presence of salt deposits in rocks in the same area support the theory of an inland sea as it is indicative of water salinity. Similar salt deposits are found in dried up lakes or ocean beds.

Dinosaur Lungs

Dinosaurs and their fossils are constantly teaching us about the environment of the past. Dinosaurs have unique traits that gave them excellent evolutionary advantages – a reason why they were dominant for such a long period of geological time.

A new study (https://www.earth.com/news/dinosaurs-lungs-little-oxygen/ and the *Royal Society Open Science*) has shown that dinosaurs did not live in an oxygen rich environment. It can be determined that 65 million years ago, oxygen levels were significantly lower than they are now. It was assumed originally that the dinosaurs had large lungs in an oxygen rich atmosphere – which could explain their size. By looking at the lung cavities of dinosaur fossils it has been discovered that even though they were quick, agile and some were quite large, their lungs were not what we thought.

The fossils show lung cavities were much like those of modern birds – designed for maximum breathing efficiency. Easily compared to lungs of alligators and ostriches, both related to dinosaurs. Alligators have smooth lungs, and the ostrich has a furrowed, rigid lung cavity providing lots of support (ribs are embedded within lung tissue).

By comparing the lung impressions of dinosaur fossils and knowing through fossils that dinosaurs lived in mostly hotter, humid climates due to lack of oxygen, it is safe to suggest their environment was poor in oxygen and had higher volumes of greenhouse gasses.

The significance of the Cambrian Explosion:

The Cambrian period, part of the Paleozoic era, is the event never, or since, seen in geological time. An explosion, or abrupt appearance of a huge diversity of complex life occurred. The most significant of this burst of biological diversity is the appearance of complex organisms including chordates – the initial vertebrates from whom we have evolved.

This one-time surge of abundant lifeforms likely occurred due to the rise of oxygen in the atmosphere. What is clear is that that burst of life included many major animal groups which have evolved and survived to this day – including mammals.

Research: Identify specimens of each of the following and describe the time and environment in which they lived:

	Diagram (labelled sketch)	Time Period of Existence	Environment
Ediacaran Fauna			
Trilobites			
Dinosaurs			
Ammonites			

Archaeocyatha			
Graptolites			
Megafauna (e.g. diprotodonts)			

The end of the Cretaceous Period and the extinction of the dinosaurs:

The extinction of the dinosaurs occurred 65 million years ago and is considered one of a handful of documented mass-extinction events. At the time of the extinction of half of the world's species, most dinosaurs went extinct (exception some avian dinosaurs). The ocean almost lost all life due to the death of the producer plankton and most vegetation disappeared. More than half of Earth's diversity was wiped out; most significantly the dinosaurs, giving rise millions of years later, to the now dominant mammals. Other survivors of this significant event include turtles, crocodiles, snails, starfish and some climate resilient plants.

This mass extinction event separates the end of the Cretaceous and the beginning of the Paleogene, but the cause of the extinction is unknown. The two most well supported hypothesis are an asteroid impact, or a massive wave of volcanic activity.

Both theories are more likely than climate change because of not only the speed of the mass extinction, but the fact that climate change takes time. Significantly, the inability for so many species to adapt to a changing climate and go extinct is highly unlikely.

<u>Theory 1: Asteroid</u>

The asteroid theory has merit Rock dated exactly 65 million years ago is rich in the metal *iridium* – rare on Earth but found in meteorites. In the Gulf of Mexico, a 180km wide crater has been dated to 65 million years ago. Known also as the Chixulub Impact, this asteroid theoretically could have created enough fallout to cause massive damage to the Earth. The impact theoretically could have vaporised the meteorite, sending iridium global.

It is also no secret that Earth's history is plagued with asteroids impacting the surface – even another planet forming our moon. The idea that a larger asteroid also hit the surface is not completely unlikely. With a significant asteroid hit, the debris could have covered the skies in soot and greenhouse gasses, blocking sunlight, preventing photosynthesis and throwing Earth back into a greenhouse gas atmosphere.

Theory 2: Volcanic Activity

Earth's core is also rich in iridium, as during Earth's formation, the heavier metal elements sank into its centre with gravity.

Scientists have evidence that a mass volcanic event occurred 65 million years ago. There is evidence flows of magma several kilometres thick covered some continents. This could explain the iridium in the rock and it could explain the atmosphere.

Should a significant amount of volcanic activity occur, magma itself would kill any animal or vegetation in its path and it would deposit the iridium in the lithosphere. Significant volcanic activity could also account for the rise in greenhouse gasses in the atmosphere – turning the oxygen rich environment toxic and suffocating. Toxic dust, gas and ash could have been in the atmosphere for months, blocking sunlight and preventing photosynthesis, further preventing oxygen creation.

Both?

Both hypotheses have excellent evidence and scientific backing. Many scientists believe both an asteroid and volcanic activity could have contributed to the mass extinction event. Should a large enough asteroid impact earth hard enough, its impact could obliterate the asteroid, sending debris into the atmosphere. The force in theory could have set off a chain reaction of volcanic activity globally. This very well could explain the sudden change in atmosphere, global evidence of iridium and almost complete worldwide wipe out of biotic life.

Activity:

In pairs, come up with a debate, or scientific discussion, regarding the asteroid vs volcano theories and which is more plausible. Come up with arguments **for your theory** and **against your partners** and at the end of your debate, suggest why one theory is more likely than the other.

Theory: ____

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Arguments FOR	Arguments Against Theory:

Discuss which theory is more plausible and why.

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Scientists recognise six waves of extinction in the past half billion years.

Causes of past mass extinctions:

Mass extinctions are when at least half of all species die out in a relatively short time. The largest mass extinction 250 million years ago saw 95% of all species go extinct. Though mass extinctions are deadly and devastating events, they give way for new species to flourish and a change in diversity to occur.

Cambrian Explosion and Extinction (540 MYA)

Though the Cambrian started with an explosion of diversity and complex organisms, it ended with mass extinction. About 40% of all species went extinct.

The original climate was warmer, oxygenated air and warm oceans. It has been suggested that the Cambrian extinction occurred due to colder climates and the appearance of glaciers. When glaciers form on land, they take water from the sea, reducing sea levels. Glacial ice would have locked up free ocean water, reducing oxygen availability.

This climate change and cold event caused the first mass extinction of geological time.

Cambrian Trilobite Image: https://study.com/academy/lesson/causes-of-the-cambrian-period-extinction-event.html

Ordovician-Silurian Extinction (440 MYA)

This extinction saw most small marine organisms including brachiopods,

conodonts and trilobites go extinct. As much as 85% of all life was eradicated making this the second most deadly extinction event. Even more concerning was the fact that this extinction was a glaciation event and most species on Earth at the time lived in the oceans. Experts suggest this extinction happened in two waves, a million years between them. It has been long believed an ice age froze all water and the second extinction event occurred because when the ice melted rapidly, the oxygen poor water released interrupted ocean currents and deprived living animals of oxygen.

Devonian Extinction (365 MYA)

Of the Palaeozoic era, the Devonian extinction is likely caused by an asteroid. The Devonian period had the first forests and strong plant life. The mass extinction, which particularly affected marine creatures killed 70% of species.

Skeleton of *Eryops*, one of the earliest land-walking tetrapods Image: https://www.livescience.com/37584-paleozoic-era.html

The mass extinction event does not seem to have a singular reason. This event seems to have come from a shift in climate. It seems likely the extinction occurred because of a lack of oxygen in the ocean, causing dead zones and therefore a reduced access to oxygen in the oceans. The impact on oceanic life seemed to be much greater than terrestrial life.

Permian-Triassic Extinction (250 MYA)

Also known was the Great Dying, the Permian-Triassic extinction was the largest mass extinction in Earth's history, impacting 95% of species on land and in water.

This mass extinction was likely caused by massive volcanic activity. The Siberian Traps were lava flows created by a plume eruption. Magma in mass quantities made its way to the surface, exploding hundreds of thousands of cubic kilometres of lava onto Pangaea. The result is a massive outpouring of magma in violent eruptions. These events last millions of years.

Part of Siberian Traps in Russia Image: https://study.com/academy/lesson/permian-triassic-mass-extinction-event-causes-facts-end.html

Triassic-Jurassic Extinction (210 MYA)

With a series of massive volcanic eruptions and rapid climate change too quick for evolution to counter, 80% of species on land and sea perished. This extinction event gave rise to the dominance of the dinosaur species.

Cretaceous – Tertiary (65 MYA)

The extinction event that wiped out over half of life on Earth. Two standout theories include an asteroid impact, supported by the presence of the Chixulub Crater in Mexico, and massive volcanic activity. Both theories can be used to explain the mass climate change that occurred immediately after as well as the mass extinction of plants and animals.

Holocene (Present)

Human induced mass extinction. The only time one species on earth has been responsible for the mass extinction of other species on the planet. Human induced climate change, pollution, trophy hunting, poaching, deforestation, carbon bombing, mining, overfishing and ice cap melting will lead to the 6th biggest extinction the world has ever seen.

Activity:

Explain the benefits of mass extinction events

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Suggest reasons why more than one reason can be associated with a mass extinction event. For example, explain why climate change AND volcanoes could be responsible, but why we have not been able to pinpoint which one.

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Research one mass extinction event (excluding Holocene). Discuss which animals thrived at the time, and which came to flourish in the aftermath of the extinction event.

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Human impact on diversity:

In the geological blink of an eye, humankind has left Earth on the brink of massive climate change, and with it - mass extinction. The extinction event seems to already have started with several species becoming extinct every year; far more rapidly than ever before, excluding past extinction events.

Listed are a few ways humans have impacted the natural order.

Pollution and Ice Cap Melting

- Our litter goes into the ocean forming, for example, the Great Pacific Garbage Patch. Sea animals get trapped, swallow litter, suffocate under plastic and die because of the amount of litter in the ocean.
- Industrial revolution onwards leads to mass amounts of toxic greenhouse gasses entering the atmosphere. The constant stream of gas entering the atmosphere has led to a hole in the ozone layer allowing damaging radiation to reach the lithosphere. These gasses are also increasing global temperatures.
- Increasing global temperatures means ice starts to melt. Already there has been record ice loss in both the Arctic and Antarctic. Animals that thrive in frozen ecosystems lose food and their homes. Thawing allows trapped methane to enter the atmosphere.

Poaching/Trophy Hunting

- Animals such as lions, giraffes, sharks and boar have been hunted as a sport to endangerment.
- Rhinos and elephants have been poached to near extinction for their tusks.
- Sharks have been trophy hunted for their jaws and bragging rights, especially since Steven Speilberg's *Jaws* where the movie made people were so scared of sharks, they actively hunted them to near extinction.
- Sharks are still hunted for their fins, to make soup.

Deforestation and Carbon Bombing

- Rainforests are a major source of our atmospheric oxygen. They act as carbon sinks, trapping carbon in the trees and greenery. Setting fire to the rainforests is one method of rapid deforestation, which comes with carbon bombs – the forests release all their stored carbon into the atmosphere in one go.
- With the destruction of the rainforests, one of the worlds most ecologically diverse ecosystems, massive amount of life is lost and the impact on rainforest animals is significant.

Overfishing

- As the name suggests, humans take too much out of the ocean, too quickly for the ocean to replenish its numbers.
- With the over fishing comes massive nets which are left in the ocean for weeks at a time. These nets may be there to catch one type of fish, but more often than not, all types of marine species from dolphins, turtles, whales, sharks and birds become trapped in the nets and drown, further dwindling already low numbers.

SHE TASK: The sixth mass extinction and how humans plan to stop it.

In this task you will investigate and demonstrate a comprehensive understanding of science as a human endeavour in Earth and Environmental Science related to the Biosphere. The focus of this task is to explore human impact and the sixth mass extinction in Earth's geological history.

You will have an emphasis on the interaction between society and, for example, the application and use of Earth and Environmental knowledge, the influence and development of new technologies, or the design of solutions to problems.

This will focus on of the key concepts of science as a human endeavor in the study of Earth and Environmental Science:

Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

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6.6 Energy from the sun is converted into chemical energy in the form of biomass.

6.6.1 Explain the importance of photosynthesis in converting light energy into chemical energy that is stored in glucose.

Biomass is the total quantity, or weight of all organisms in an area or ecosystem at a time. In Earth science, biomass is measured as the mass of organically bound carbon (C) present.

Biomass can be species specific, or it can describe all species including microorganisms, plants or animals. Biomass energy is generated from plant and animal materials.

Regarding human use, biomass is a material made from plants or animals, which we convert into energy. It is considered renewable energy because we can continue to grow new plants.

Although it is not an infinite resource, there is only so much water and land to grow the materials.

When managed sustainably, biomass can give incentive to properly manage and monitor woodland biodiversity.

Biomass has a significantly reduced effect on the atmosphere as it releases less pollutants such as Sulphur dioxide.

What is biomass energy? ____

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Why is I important that biomass regards the amount of carbon present in the organism,

species or ecosystem?____

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Why would biomass be a preferred option to fossil fuels if it still produces GHG's? ________

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Photosynthesis

The sun is the ultimate source of energy in an ecosystem. The sunlight allows production in plants to occur, where organic matter is created by photosynthesis.

- Photosynthesis is an anabolic process and synthesis reaction. *Photoautotrophs* including plants, some bacteria and unicellular organisms produce glucose from sunlight, carbon dioxide and water.
- Most ecosystems rely on energy from sunlight.
- Living organisms which have chloroplasts can convert this sunlight into **chemical energy**.
- Three groups of organisms capable of photosynthesis include plants, algae and cyanobacteria.
- Living things capable of converting light energy into chemical energy are *producers.*
- Almost all organisms rely on producers to convert sunlight to chemical energy. These species need the carbon compounds in their food.
- The carbon compounds produced include lipids, carbohydrates and proteins.

Photosynthesis:

$$6CO_2 + 6\ H_2O + \text{sunlight} \rightarrow 6O_2 + C_6H_{12}O_6$$

How photosynthesis works:

- Plant cells have organelles called chloroplasts which contain the green pigment called **chlorophyll**, which absorbs light.
- The plant uses the light energy, CO_2 from the air and water from the soil to create glucose.
- Plants use the suns light energy to create chemical energy.
- This chemical energy is used directly by the organism as glucose and used to build starch. Starch consists of glucose molecules joined by chemical bonds.
- The chemical energy becomes glucose which gets converted into pyruvate.
- This releases oxygen and ATP or adenosine triphosphate.
- Excess glucose is stored as starch, a polysaccharide.
- This chemical energy is used directly by the organism as glucose and used to build starch. Starch consists of glucose molecules joined by chemical bonds.

Write a worded equation for photosynthesis.

How does photosynthesis impact upon an ecosystem's biomass? ____________________

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Explain how photosynthesis is essential to the survival of an ecosystem ______________

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Explain the benefits of biomass as a renewable energy _____________________________

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Effects of photosynthesis on Earth:

Increase or decrease in photosynthetic organisms leads to changes in the overall composition of the atmosphere. The Great Oxidation Event occurred approximately 2.4 billion years ago. The Great Oxidation Event was the most significant event in Earth's history for organisms. The theory is that single-celled organisms living in this oxygen deficient atmosphere, evolved a way to take energy from sunlight.

Cyanobacteria are believed to be the oldest living organisms, with fossils proving they existed 3.5 billion years ago. It is believed they evolved a way of consuming sunlight, water and carbon dioxide from the atmosphere and turn it into sugars; oxygen being removed as a waste product. Cyanobacteria were the first to use photosynthesis. At this time was a reduction of the greenhouse effect, likely resulting from an increase in atmospheric oxygen.

The theory of the Great Oxidation Event is simple. Cyanobacteria thrived in the environment, releasing waste product oxygen into the atmosphere. Whilst it took time for atmospheric oxygen to become significant, this event could only have occurred with bacteria evolving the ability to photosynthesize.

- Explain why this is significant and why this benefitted multicellular organisms.
- Explain how this changed the biomass and how significant photosynthesis was to this occurring.

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Net primary production (NPP) is the rate at which plants in an ecosystem produce net useful chemical energy.

Productivity is the rate energy is added to an organism's cells in the form of biomass. This biomass is the amount of matter stored in a group of organisms.

There are two types of productivity: gross productivity and net productivity.

Gross primary productivity, (GPP) is the rate solar energy is captured in the chlorophyll of photosynthetic organisms during photosynthesis. Producers use some of the energy to survive and for their own energy. From this figure, the respiration (R), the amount of carbon dioxide lost during metabolic activity is subtracted.

Net primary productivity (NPP) is the amount of carbon uptake after subtracting plant respiration from gross primary productivity. It's the rate energy is stored as biomass and made available to an ecosystem.

Net primary Production = Gross Primary Productivity – Respiration

The respiration figure can be separated into components including producers, heterotrophs and decomposers.

Net Ecosystem Production is the amount of primary production after the cost of respiration.

This energy can move from one trophic level to the next when animals and plants are consumed by others.

The most efficient way of gaining energy is to photosynthesize.

Consumers must eat producers or smaller consumers to survive. This can lead to mass energy output during hunting and loss of energy through heat and decomposition.

SCIENCE AS A HUMAN ENDEAVOUR
Biomass energy is considered "renewable energy".

- Discuss what biomass is and how it relates to plants and animals.
- Discuss the impacts of human use of biomass. Are there any drawbacks? Explain.

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Practical Investigation:

Aim: to investigate the impact photosynthesis has on volume of biomass.
Materials:

- Plastic bottles
- Soil
- Plant (one variety or two optional)
- Light source
- Water
- Beaker

Method:

1. Create three small ecosystems by cutting the bottles along the sides, creating a large square hole.
2. Into this, fill equal volumes of soil, water and plant(s).
3. Sit each under the same light source – one directly in line with the light, the next approximately 20cm away, the last another 20cm away.
4. Over two weeks, observe and record what is happening to the biosphere. Measure the growth of the original plant and qualitatively record any new plants. Include a graph.

6.7 The availability of energy and matter are one of the main determinants of ecosystem carrying capacity.

6.7.1 Explain how biotic and abiotic factors affect carrying capacity.

The carrying capacity of an ecosystem refers to the ability for the environment to support the living population indefinitely. Ecosystem carrying capacity considers the maximum population size that the environment can sustain, considering *limiting* factors such as food, oxygen, water and space.

As the population of an ecosystem grows, resources become limited. With limited resources comes competition and an increase in individuals who perish along the way.

Should a species reproduce and exceed carrying capacity, the amount of deaths will quickly outnumber births.

Suggest reasons why it is important that carrying capacity is not reached or exceeded by one species.

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Suggest ways in which ecosystems naturally prevents themselves from being overrun by a species

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Suggest the benefits of predator-prey relationships in these circumstances and discuss what could occur should the predator-prey relationship be out of balance.

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Biotic and abiotic factors are crucial for the health and lifespan of an ecosystem.

Biotic, or *living factors*.
Biotic factors are animals, bacteria, plants, fungi and decomposers.
Biotic factors relating to animals includes the rate of reproduction, but it also considers cross species relationships such as predator-prey, parasite-host.

Abiotic factors are *non-living factors* relevant to the ecosystem.

These factors include weather, soil nutrients, rainfall, sunlight, minerals, temperature, landforms.
These factors often dictate which species will be found in specific environments.
For example, plants require sunlight, rain and soil nutrients to grow. Should the climate change and increase the intensity of sunlight, reduce annual rainfall and dry out soil, the trees will likely grow smaller and weaker, if not die completely. Should this occur, the ecosystem could be severely altered.

Suggest another way an abiotic factor could impact an ecosystem.

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The predator-prey relationship dictates biotic factors in an ecosystem. Should the prey become too numerous, the amount of vegetation would likely drop, but the number of predators would increase. Should predators become too numerous, there will not be enough prey to sustain them and mass death would likely occur.

Suggest another biotic relationship and the potential consequences of knocking the relationship out of balance.

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Explain the impact on the atmosphere, should numerous ecosystems collapse.___________

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SCIENCE AS A HUMAN ENDEAVOUR

Discuss the natural carrying capacity of an ecosystem and discuss why most healthy ecosystems do not include humans.

- Explain how humans impact the environment and what they do to ecosystems.
- Discuss the impact humans have on the delicate balance of these ecosystems and suggest long term effects of this impact.
- Humans have damaged the oceanic ecosystem almost to the point of no return. Discuss how they have done this, what potential long-term effects this will have globally and what is being done to slow down or stop this impact.

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6.7.2 Discuss the benefits of ecosystem services.

Ecosystem services are processes that occur in ecosystems that achieve major transformations of resources that benefit humans.

As with every other species, humans benefit from biodiversity. Given that many species are on the brink of extinction, this will cause a drop in genetic biodiversity. Long term, the more species that become extinct, the less genetic diversity there is which harms our likelihood of survival.

There are three ways that biodiversity is crucial to human survival.

1. Direct impact
2. Indirect impact
3. ethical effect

Direct services are benefits humans get as a direct result of an ecosystem, such as food, shelter, materials for clothing and energy.
All food we eat are direct results of healthy ecosystem function.
All medicines we have today are derived by studying the way organisms survive in their environment. A loss of biodiversity means the likelihood of finding cures or treatments in the future declines.

Indirect services mean humans do not see the direct benefit of these organisms, but in fact experience the benefit second hand.
Rainforests are natural carbon sinks – they take mass volumes of carbon dioxide out of the air and replace it with oxygen. Whilst we do not directly benefit from the rainforest itself in that way, they provide us air to breathe.
Unfortunately, rainforests are being so rapidly destroyed, all the stored carbon dioxide is being released back into the atmosphere and the carbon dioxide that would have been consumed by photosynthesis simply stays in the atmosphere increasing the volume of greenhouse gases.

Ethical effect or aesthetic effect is a very important service.
The ethical value is hard to put a price on. This refers to what we leave for the future.
A loss of biodiversity and a high extinction event in our near future will impact our future generations negatively.
Humans are responsible for maintaining and protecting ecosystems, yet day to day industrial and even personal activities harms the environment. Pollution, over fishing, habitat destruction and increase in climate temperatures leads to a future where there is minimal stability environmentally and the sustainability of food and water decreased.

SCIENCE AS A HUMAN ENDEAVOUR
Humans are responsible for the health and biodiversity of the biosphere. Should the biosphere be harmed, long term effects on us could be detrimental.

- Briefly explain why humans are not considered in most healthy ecosystem diagrams.
- Discuss what ecosystem services are and how humans' benefit.
- Discuss the suggestion that the human population is already significantly past Earth's capacity to support us.
- The UN Paris Agreement was signed as a global acknowledgement and recognition of the impact we as a human race is having on the biosphere, atmosphere and overall climate. The goal is to set limits of carbon and greenhouse gas emissions to prevent global, long term temperature rise. Discuss the possible future we leave future generations should this agreement fail.

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6.8 Energy is stored, transferred, and transformed in the carbon cycle.

6.8.0 Carbon

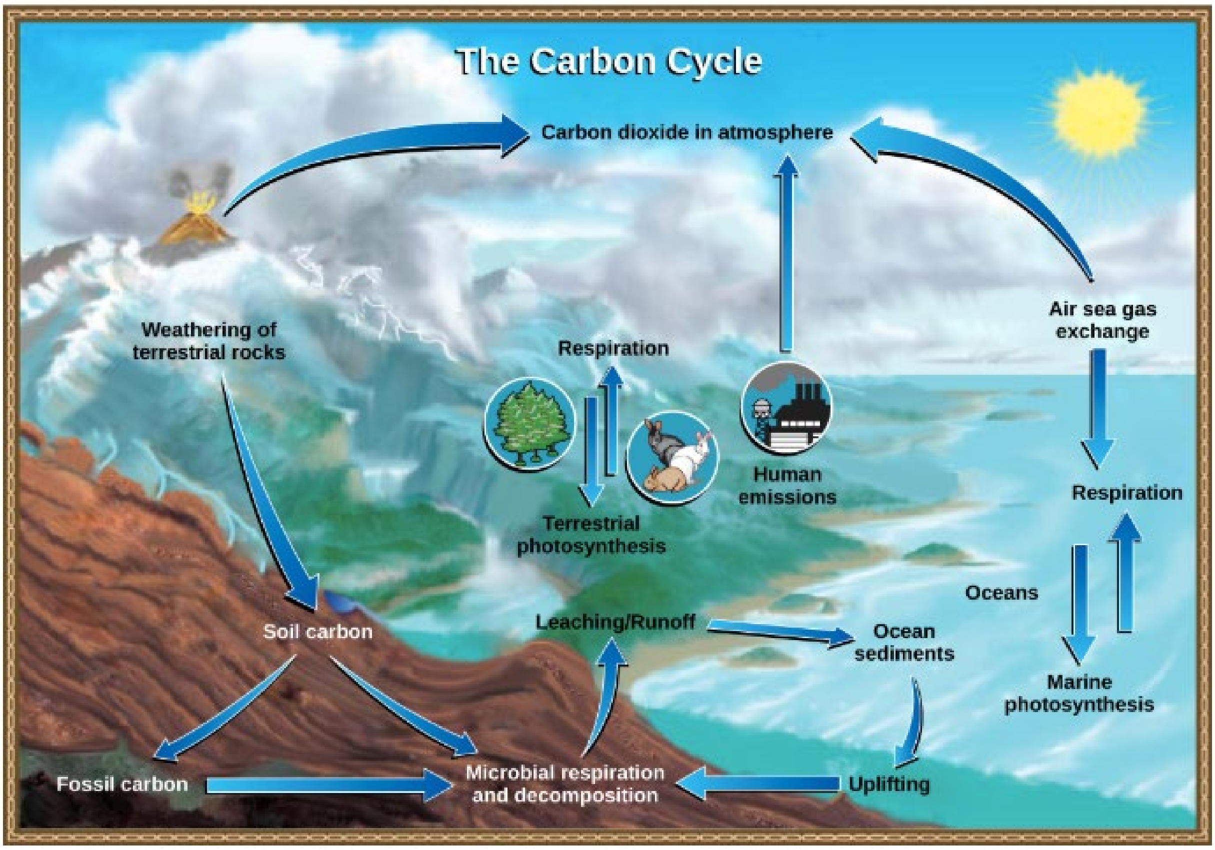
Carbon is an essential element in living organisms and is also important to humans in the form of fossil fuels. Carbon dioxide from the atmosphere is absorbed by photosynthetic organisms to create simple sugars and provide energy for the food chain.

The carbon cycle makes earth unique among planets. Carbon is the backbone of earth's ability to produce and sustain life. We are made of carbon, we eat carbon and we mine carbon in the form of fossil fuels. Unfortunately, the most globally significant element is also the one causing us the most trouble: global climate change.

Current climate chance is thawing permafrost, which is releasing trapped methane (CH_4) and extra carbon dioxide into the atmosphere. This along with an increase in the demand of fossil fuels and deforestation add to atmospheric carbon dioxide and increasing the greenhouse effect, warming temperatures even further.

6.8.1 Describe the key processes and the role they play in the carbon cycle, including photosynthesis, respiration, decomposition and combustion.

The carbon cycle is diverse and involves the following key processes.



Resource: https://www.khanacademy.org/science/biology/ecology/biogeochemical-cycles/a/the-carbon-cycle

Carbo
n exchange across the four spheres is called the carbon cycle. This cycle is ongoing and has components that occur quickly and components that take millions of years. Any change in this cycle could result in less carbon in some areas and more carbon in others.

There are four key processes that occur in the carbon cycle:

1. Photosynthesis
2. Respiration
3. Decomposition
4. Combustion

There is a preexisting relationship between photosynthesis and respiration. Whilst photosynthesis takes CO_2 out of the air, cellular respiration releases CO_2.

Photosynthesis

Removes carbon from the atmosphere. Photosynthesis involves the plant, or other photosynthetic organism, absorbing sunlight and carbon dioxide from the air.
These autotrophs are beneficial not just because they create simple sugars which feed us, but because they take greenhouse gasses like carbon dioxide out of the atmosphere and replace them with oxygen, cooling the overall atmosphere.

Carbon 'fixing' refers to chemically altering carbon dioxide gas into solids such as glucose sugars.

Photosynthesis:

$$6CO_2 + 6\ H_2O + \text{sunlight} \rightarrow 6O_2 + C_6H_{12}O_6$$

Respiration

The exact opposite of photosynthesis. Aerobic cellular respiration produces carbon dioxide as a waste product and passes into the surrounding atmosphere or water.

Animals and other heterotrophs depend on photosynthesis for food, air to breathe and energy.

When organisms go through respiration, they return CO_2 to the atmosphere.

Algae, which is found in or near water, relies on the CO_2 from the air to mix with the water, producing carbonic acid, which breaks down bicarbonate ions – their food source.

During respiration, algae releases bicarbonate which goes hand in hand with the volume of CO_2 in the atmosphere.

Respiration:

$$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6\ H_2O + ATP$$

Decomposition:

Decomposers include mushrooms, fungi, algae and microscopic organisms such as bacteria.

Decomposers work to break down dead organisms, recycling nutrients back into the ground and atmosphere. These decomposers release CO_2 from the decaying material and it is released back into the atmosphere through respiration.

With the negative impact humans have on ecosystems, decomposers are breaking down more and more plant matter, releasing more CO_2 back into the atmosphere.

Combustion

Carbon dioxide is again produced and released into the atmosphere by burning biomass and fossilized organic matter such as fossil fuels.

If organic matter burns, in the presence of oxygen, combustion occurs and releases CO_2 into the atmosphere.

Combustion in some areas is perfectly natural – natural grass fires occur, and biomass is burned releasing CO_2 into the atmosphere. In natural environments, the ecosystem can bounce back, and the grass or forest can quickly regenerate, even slightly healthier.

Human activity has significantly increased the amount of carbon dioxide being released into the atmosphere. Industry, among other things, requires numerous combustion reactions to occur, almost constantly releasing carbon dioxide.

As part of deforestation, humans burn down enormous volumes of rainforest, replacing it with palm oil plantations. Not only does this damage a natural carbon sink, it releases large volumes of carbon dioxide in a short time frame.
In agriculture, humans burn sugar crops before harvest – another combustion reaction.

Our biggest contribution to carbon emissions comes from our fossil fuel addiction. Fossil fuels including oil, natural gas and coal are burned in unsustainable quantities. The carbon found in these natural resources was removed from the atmosphere millions of years ago, as part of the slow carbon cycle.

Burning these fossil fuels means the volume of carbon entering the atmosphere as either CO_2 or CH_4, traps heat inside the atmosphere, increasing global climate temperatures and thus, significantly fast-tracking climate change.

Explain the main differences in the photosynthesis equation and respiration

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What is the most beneficial process that occurs in the carbon cycle, and why?

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Why is respiration ultimately harmful to us, if we need it to survive?

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Explain the benefits of decomposers, even though they release CO_2 back into the atmosphere.

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What is the difference between natural and human influenced combustion?

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Explain the role of decomposers to the carbon cycle. What would likely occur, should decomposers go extinct?

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How significant are producers to the ecosystem?

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Suggest two effects deforestation has on the carbon cycle.

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Suggest three abiotic factors that could influence the growth of trees

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Describe the effect of deforestation on the oceans.

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The main carbon sinks

A carbon sink is a natural or artificial environment, which removes or absorbs more carbon dioxide from the atmosphere than what they put back into it.

Forests remove large volumes of CO_2 from the atmosphere by photosynthesis. When the plant or tree dies and starts decomposing, lots of the carbon is transferred to the soil.

The oceans are major carbon sinks, absorbing mass loads of CO_2 from the atmosphere. Often the CO_2 dissolves in the water.

Natural carbon sinks have a maximum limit of CO_2 they can absorb safely. When the ocean absorbs too much CO_2, ocean acidification occurs.

Explain why the ocean is considered a carbon sink.

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Explain why rainforests are considered carbon sinks

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The rate of rainforest deforestation has increased rapidly with advances in technology and machinery. Explain the side effects of such efficiency on the natural carbon sink, atmosphere and, thus, the climate.

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Explain what ocean acidification is. How does it work and what does this tell us about the overall health of the ocean? Explain what ocean acidification tells of the oceans ability to absorb carbon and discuss the long-term effects of increased acidification.

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The fast and slow carbon cycle.

Most of Earth's carbon is stored in rocks, however the ocean, atmosphere, plants and soil, and fossil fuels still contain large quantities.
Carbon flows between systems changing from gas to solid and back to gas again. This occurs throughout the carbon cycle.

The carbon cycle has a 'fast' component, where regular carbon exchange occurs, and a slow component which takes millions of years.

The *fast* carbon cycle includes the oceans, atmosphere, and living organisms. Photosynthesis occurs on land and in the ocean whereby CO_2 is removed from the atmosphere and into the organism.

The fast cycle can be related to the seasons – during spring and summer, with high sunlight, plant activity is increased, and the amount of CO_2 removed from the atmosphere is high. During autumn and winter, cooler climates where plant activity decreased due to death or going dormant, annual atmospheric CO_2 increases.

The *slow* carbon cycle is more geological – looking at Earth's crust. This part of the cycle can take millions of years. The slow cycle refers to carbon moving from the soil, into the rocks, deep in the ocean and into the atmosphere. Significant amounts of carbon are released rapidly into the atmosphere during volcanic eruptions.

If the carbon came from an organic source, over millions of years of compression and heat, this organic litter becomes fossil fuels which we obtain through mining and burn at tremendous speeds.

Differentiate between the fast and slow carbon cycle.

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What could be the long-term repercussions on the carbon cycle if fossil fuel deposits run dry?

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Processes in the carbon cycle.

Key Process	Where it occurs
Photosynthesis	- Occurs in the fast carbon cycle. - Producers including plants, algae and microorganisms are responsible - Plants consume carbon dioxide and water to make sugars and release oxygen as a byproduct. - Directly removes carbon dioxide from the atmosphere. - Carbon is photosynthesized by autotrophs and converted from a gas to a solid in the form of sugars CH_2O. - Should the plant die, some carbon dioxide is released back into the atmosphere and some carbon is absorbed into the soil. - The health of the producers directly impacts the health of the overall ecosystem.
Respiration	- Most respiration can only occur further up the food chain. - Respiration occurs as part of the fast carbon cycle. - Animals that respire must first consume the producer to gain access to the stored carbon in its sugars. - Most consumers respire by breathing in oxygen and consuming glucose provided by producers. Respiration releases carbon dioxide back into the atmosphere and water. - Respiration releases carbon in a gaseous form back into the atmosphere. - A decline in producers leads to a decline in carbon moving through the carbon cycle. - Should the carbon cycle slow, due to a loss of producers, there will be more carbon dioxide in the atmosphere.

	- Should the consumers die, they will release carbon dioxide as a gas, but lots will be absorbed into the soil.
Decomposition	- Part of the fast carbon cycle. - Decomposers work to break down dead organisms and biomass - Through the decomposition process, the decomposers such as fungi and bacteria respire. - Some carbon is absorbed through soil.
Combustion	- A result of organic matter burning in the presence of oxygen. - Natural combustion reactions use oxygen and release carbon dioxide into the atmosphere in reasonable quantities. - Any biomass that was not completely burned will release carbon into the soil upon decomposition. - Human influenced combustion releases mass quantities of carbon dioxide, carbon monoxide and methane into the atmosphere. - Combustion reactions burn away biomass so if burning was to occur in a rainforest, the carbon sink would be improvised.

Explain the interactions between the forms of carbon and each of the spheres.

The four spheres include:

Biosphere *hydrosphere*
Atmosphere *geosphere*

Biosphere

All life on Earth is in the biosphere. The biosphere can be broken into several ecosystems or considered one whole ecosystem.

Carbon enters the biosphere through the autotrophs who use it with water to create organic compounds such as glucose, providing a food source, and is either returned to the atmosphere as a gas from the respiration process or absorbed into the soil during decomposition. Heterotrophs access carbon through food chains and webs.

Throughout the biosphere, living autotrophs, or producers remove atmospheric carbon and produce organic carbon through photosynthesis. Most of this organic carbon moves through organisms up the food chain. Some of this carbon is released back into the atmosphere via respiration.

In death, the decomposers respire carbon back into the atmosphere, but some organic carbon is released into the soil.

Hydrosphere

Carbon is found in the hydrosphere as carbon dioxide dissolved in the water. Similarly, to the biosphere, algae, plants and bacteria convert it to organic carbon through photosynthesis. Carbon can be moved through the marine food chain from organism to organism. This carbon is used by the organisms to produce food, sugars and support life.

Marine mammals respire and release carbon dioxide into the atmosphere. Other organisms, upon death, will be broken down by marine decomposers.

The marine decomposers respire and release carbon back into the atmosphere. The ocean itself can dissolve carbon and trap it in the water.

The hydrosphere is a giant carbon sink. Carbon dioxide is absorbed by and stored in the water where it becomes less soluble as the water temperature increases. This property of carbon dioxide has implications for a negative feedback look, which is likely to affect the rate of global warming as ocean temperatures rise.

Both the hydrosphere and biosphere have *permafrost.* Permafrost is frozen soil which is quite rich in organic carbon, mostly in the form of methane hydrates. When frozen, the organic carbon is not part of the carbon cycle because it is dormant in those conditions. Due to climate change, temperatures are rising, thawing the soil. On top of this, decomposition increases, and large amounts of methane will be respired back into the atmosphere. Methane is a much more dangerous, potent greenhouse gas than carbon dioxide. One molecule of methane is equivalent to 23 molecules of carbon dioxide in the atmosphere.

Geosphere

Organic carbon is held in the soil. Carbon can leave the soil by being consumed by flora, or through erosion, carrying the carbon into nearby water bodies. This carbon is now part of the hydrosphere.

The geosphere is part of the slow carbon cycle. Carbon can be stored in limestones and fossils within rock, buried within the Earth's crust. Through lithification, the organic matter is converted into crude oil, or fossil fuels. This takes millions of years.

The organic matter is harmless and stable within the lithosphere. Human influence of drilling into the crust, to gain access to the fossil fuels brings stored, inactive carbon back into the active cycle. Industry burns the carbon at rates that change the balance of the carbon cycle.

Natural geological processes of plate tectonics can cause subduction of the crust where the fossil fuels are stored. Should this occur, the organic carbon is transformed into carbon dioxide. This carbon dioxide can be released through volcanic eruptions, bringing the gas back into the atmosphere.

Atmosphere

Approximately 0.04% of the atmosphere is carbon dioxide and 0.00017% is methane. Whilst it seems insignificant, the amount of carbon dioxide being added to the atmosphere annually, by human impact alone increases the volume and thus increases the amount of greenhouse gases.

Carbon dioxide is released into the atmosphere by respiration from living things and decomposers. These activities also release methane into the atmosphere, which is more potent than carbon dioxide and a stronger greenhouse gas.

Carbon dioxide is also released into the atmosphere via combustion, which is becoming significant.

Carbon is only removed from the atmosphere via photosynthesis and via carbon sinks.

This massive increase in carbon dioxide in the atmosphere and the impact of humans on natural carbon sinks is throwing the carbon cycle out of sync and can have long term effects on the climate.

Questions

Suggest long term effects of removing stored carbon from deep within the crust.

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Explain how carbon is moved through the slow carbon cycle.

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Suggest the effects of losing our carbon sinks on the atmosphere.

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Explain how a shift in the carbon cycle can be detrimental

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Explain how the carbon cycle influences the climate and what kind of future environment this could lead to.

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Investigation Design Practical: Carbon Dioxide Levels in Varied Water Temperatures

Aim:

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Hypothesis: ____

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Materials:

Procedure:

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Results: (Draw Table)

Graph:

6.9 Biogeochemical cycling of nitrogen and phosphorus in matter occurs between the geosphere, atmosphere, hydrosphere and biosphere.

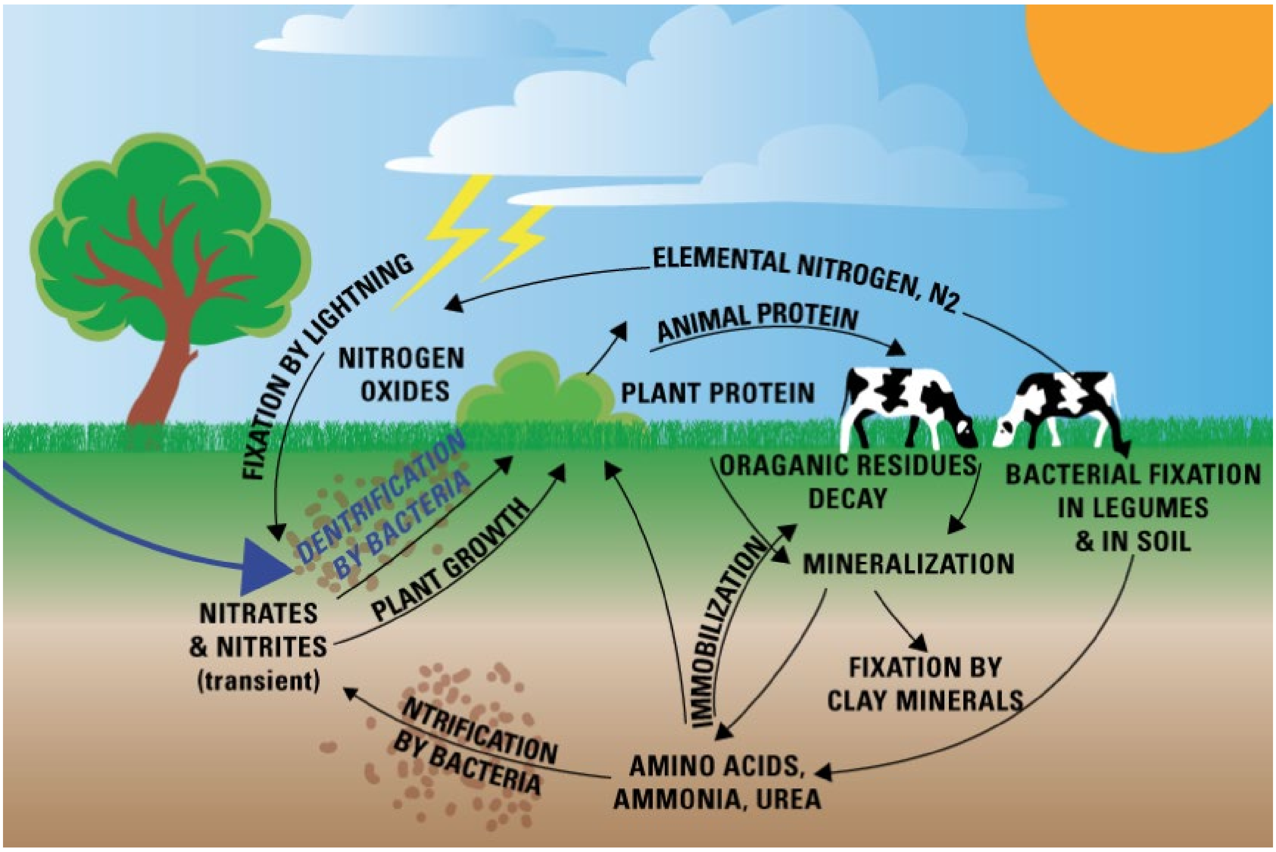
Biogeochemical cycles explain the movement of nutrients through the four spheres to adapt to an evolving ecosystem.
Key processes in the nitrogen cycle including nitrification, denitrification, nitrogen fixation, ammonification and eutrophication.

Nitrogen is a chemical element essential to life and is comprises approximately 78% of the atmosphere.

Nitrogen is used to make amino acids, proteins, DNA and ATP in organisms. These organisms can only obtain nitrogen in a water-soluble form, through soils.

Molecular nitrogen, N_2, is fixed by bacteria in the soil, converting it into an accessible nitrogen source.

The Nitrogen Cycle



Resource: https://www.greenpeace.org/international/story/18170/how-can-we-restore-earths-nutrient-cycles/

Atmospheric nitrogen is inaccessible to living things. As such, a series of reactions need to occur. Some of these reactions must occur sans sunlight.

Nitrogen Fixation (N_2 to NH_3/ NH_4+ or NO_3-)

Nitrogen-fixing bacteria use enzymes to convert atmospheric nitrogen into organic compounds available for consumption. This nitrogen is often absorbed through plants and grass.

Nitrification (NH_3 to NO_3-)

Bacteria oxidize ammonia and waste in the soil, converting it to nitrates and nitrites.

Denitrification (N_2)

Again, bacteria remove nitrogen and other nitrogen compounds from the soil, converting them into atmospheric nitrogen. This N_2 gas goes into the atmosphere.

Ammonification (NH_3 or NH_4^+)

Ammonification only occurs because of the presence of decomposers. As they break down the organism, they release nutrients into the ecosystem. They change the organic nitrogen found in the organisms into ammonia or ammonium ions.

Eutrophication

Eutrophication can be a natural process and involves large amounts of nitrogen and phosphorus entering water bodies. Eutrophication is also accelerated due to the runoff of fertilizers. Fertilizers and manure are high in nitrogen.

Explain the difference between nitrification and denitrification

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Which of the above processes must occur without the presence of sunlight, and why?

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Explain what occurs when the nitrogen cycle is impacted by severe weather events

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Explain the effects of desertification regarding the nitrogen cycle on an ecosystem and environment.

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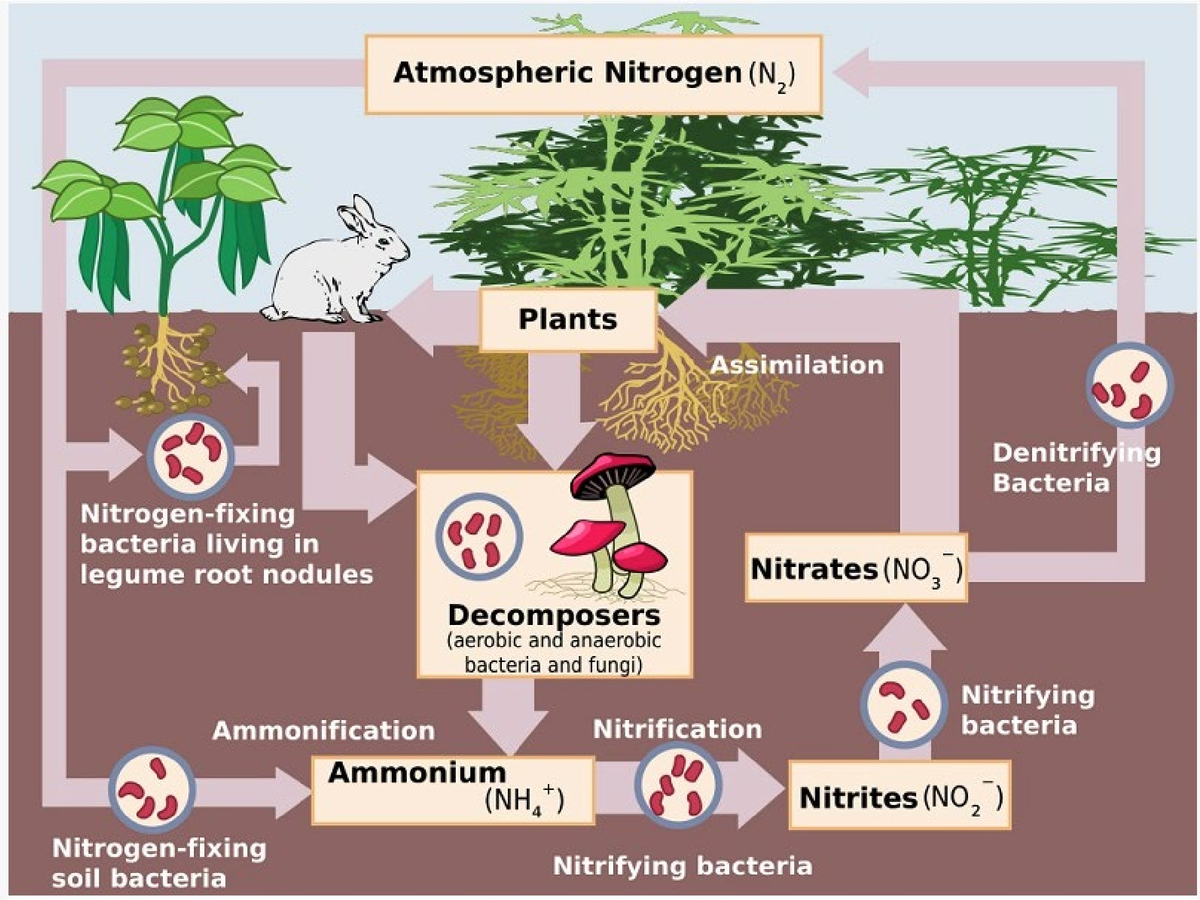
6.9.2 Identify where these processes occur in the nitrogen cycle.

Nitrogen is a chemical element essential to life and is comprises approximately 78% of the atmosphere.

The key to understanding the nitrogen cycle is knowing that *fixation* is a reduction and *denitrification* is oxidation. Nitrogen moves through the atmosphere, ocean, biosphere and lithosphere through specific chemical reactions.



Resource: https://biologydictionary.net/nitrogen-cycle/#prettyPhoto/0/

Nitrogen fixation is the beginning of the cycle whereby atmospheric nitrogen is removed from the atmosphere by bacteria and changed into organic nitrogen, or ammonia. This can be dissolved in water.

Nitrification follows, where bacteria convert the ammonia nitrogen dioxide, then into nitrate. It's this nitrogen compound that autotrophs can consume, referred to as assimilation.

Ammonification is the decomposers way of continuing the nitrogen cycle. During decomposition, nitrogen is removed from the organism and absorbed back into the soil to be reused.

Denitrification is where the nitrates in the soil are converted back into molecular nitrogen by anaerobic bacteria. This molecular nitrogen is returned to the atmosphere.
Interactions between the forms of nitrogen and each of the spheres.

The four spheres include:

Biosphere *hydrosphere*
Atmosphere *geosphere*

Biosphere
The biosphere, where all life I found, cannot survive without the presence of nitrogen. Whilst the nitrogen is not accessible as molecular nitrogen in the atmosphere, the living things within this system must wait until bacteria in the soil do the heavy lifting.

Most organisms in the biosphere can only consume nitrogen through the food chain. Autotrophs are the key link between stored nitrogen in the soil, and accessible nitrogen to support life and the ecosystem.

When the nitrogen becomes organic, a nitrate, plants and other autotrophs can absorb the nitrogen through their roots. Once this has occurred, the nitrogen is accessible to the consumers. It travels up the food chain from organism to organism.

Upon death of the organism, decomposers break down the tissue and through the process, release nitrogen back into the soil to be recycled.

Hydrosphere
Nitrogen in the hydrosphere is as inaccessible as the biosphere without the algae and other photosynthetic organisms.
Similarly, through decomposition, nitrogen is released back into the ocean for recycling.

Nitrogen can also enter the hydrosphere via eutrophication. The runoff or excess from solid or river flow introduces large quantities of readily available nitrogen to the water source.

Even in the hydrosphere, there is an availability of bacteria which can denitrify the nitrogen, converting it back into atmospheric nitrogen and releasing it to the atmosphere.

Atmosphere
Most of the atmosphere consists of nitrogen. The nitrogen is useless in its atmospheric form to the biosphere, so it must be converted.

Nitrogen in the atmosphere can, through lightning, become fixed, and available to the biosphere without the need to go through bacteria. Although this does occur, it is not frequent enough to support an ecosystem without the support of the bacteria.

Atmospheric nitrogen combines with oxygen at high temperatures and appropriate pressure conditions. This causes a form of nitrogen oxide and is increased with industrial combustion. Nitrogen oxides form smog found especially during the industrial revolution.

Geosphere
Most of the chemical reactions of the nitrogen cycle occur within the geosphere.

The soil is packed with bacteria which can convert nitrogen into organic molecules, moving from nitrogen to nitrogen dioxide to ammonia. This allows nitrogen to enter the biosphere and allows the biosphere to remain healthy. Should the bacteria stop fixing nitrogen, the ecosystem would suffer.

In extreme weather or in heavy rain runoff of soil and fertilizer can enter a water source, called eutrophication. This provides a boost to the water system nutrient wise, but the area that lost the soil could suffer from this loss.

Losing the soil means losing the bacteria within the soil which harms the environmental ability to treat and move nitrogen.

Bacteria within the soil convert molecular nitrogen to ammonia, and convert any excess back, through several reactions, to molecular nitrogen to be release back into the atmosphere.

Explain the effect nitrogen has on the oceans

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Explain why bacteria are crucial in making nitrogen available to the environment.

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Discuss the effects of flooding on an environment. Discuss the benefit to the water source and the harm caused to the land.

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Explain the effects of desertification to soil health and long-term effects on the health of the soil. Should the bacteria suffer, can the soil be saved?

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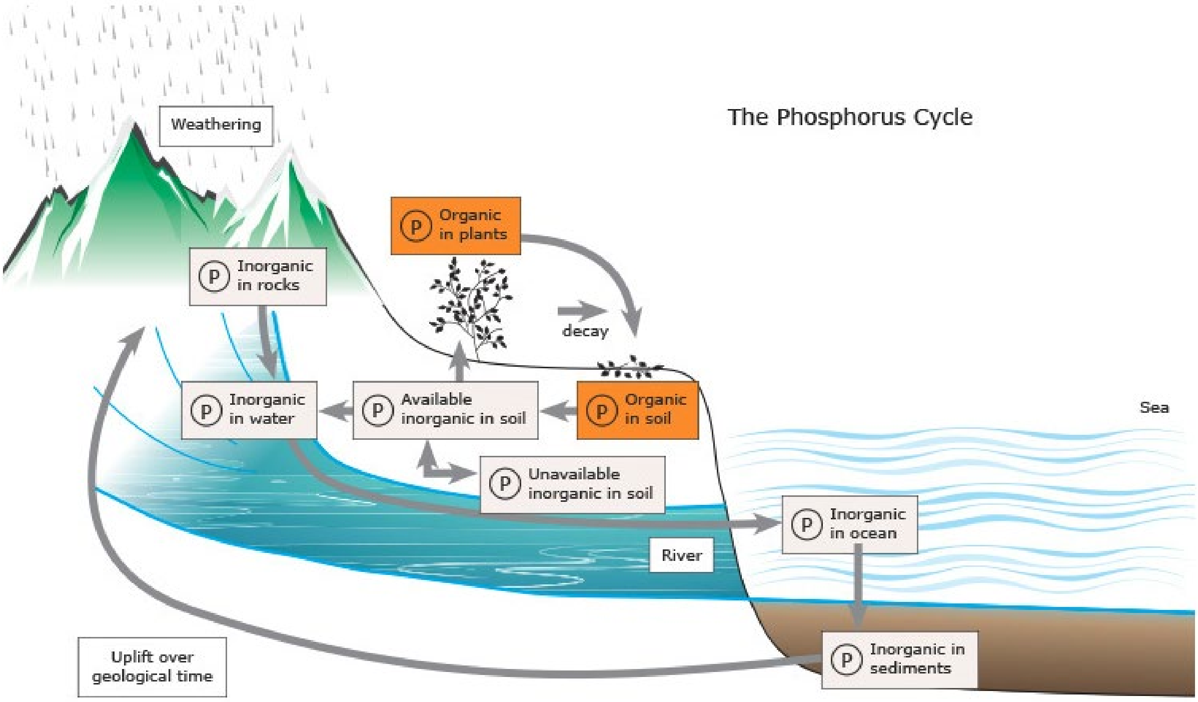
The Phosphorus Cycle

Unique to the phosphorus cycle, is the absence of the atmosphere. Phosphorus lacks a gaseous form and thus, does not interact with the atmosphere. In nature, phosphorus is referred to as a *limiting nutrient*. This is because its cycle takes the longest meaning phosphorus is always in demand and in short supply. This particularly impacts growth patterns of marine ecosystems.

Phosphorus is important to plants and animals to build DNA, ATP and phospholipids. Phosphorus is primarily found in rocks. Because weathering and erosion needs to occur to release phosphorus into the soil, the phosphorus cycle is actually quite slow.



Resource: https://www.sciencelearn.org.nz/resources/961-the-phosphorus-cycle

Phosphorus is mainly found in the lithosphere – as part of rocks. Abiotic factors including rain, erosion and weathering erodes these rocks. Erosion processes make phosphorus available to the soil.

Once in the soil, microorganisms grow by consuming the phosphorus. Phosphates are absorbed from the soil by plants. These plants absorb phosphorus just like they do nitrogen, through their roots.

From this action, phosphorus is now available to the ecosystem and heterotrophs which will move the phosphorus up the food chain.

Phosphorus is returned to the soil or water via waste and decomposition.

Like the movement of nitrogen, phosphorus enters water bodies through soil movement including erosion and runoff. It leaves water by sedimentation into rocks.

Phosphorus is found as both *organic* and *inorganic phosphate.*

Organic phosphates, or organophosphates are esters of phosphoric acid. Inorganic phosphates are salts of phosphoric acid. Inorganic phosphates are unavailable to the biosphere. They are found in rocks, water and sediments. Through bacterial intervention, phosphorus can convert phosphorus into organic phosphates which are available to the biosphere. Plants absorb the organic phosphates from the soil and this phosphate is moved through the food chain. Through death and decomposition, organic phosphates are deposited back into the soil.

Explain the difference between organic and inorganic phosphorus

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Explain why the phosphorus cycle does not include movement through the atmosphere.

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Explain why phosphorus is considered a limiting factor and what can be done to improve this on

farms. ____

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Explain how phosphate moves through the ocean

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The atmosphere does not play a big part in the phosphorus cycle, but it does in the nitrogen cycle.

The atmosphere is a big contributor to the nitrogen cycle because most of the atmosphere is comprised of nitrogen. The nitrogen in the atmosphere is abundant and is readily available to the biosphere and hydrosphere. The movement between the nitrogen in the atmosphere and the other four spheres is quick and constant.

Regarding the phosphorus cycle it is unique because it does NOT involve the atmosphere. Processes involved in weathering such as rainfall come from the atmosphere, but phosphorus does not have a gaseous form naturally and therefore cannot physically be part of the atmosphere. This eliminates the atmosphere almost completely from the cycle.

Extended response.

Considering **one of** carbon, nitrogen or phosphorus, explain the cycle itself and explain why these cycles show uniformitarianism.

Explain the effects of your chosen cycle on the natural ecosystems and what effects could occur if more or less of this element were globally available.

Discuss the impact your chosen cycle has on agriculture and farming and what is being done to overcome or support the cycle.

Consider the cycle regarding greenhouse gases and climate change.

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Resources

- http://ib.bioninja.com.au/standard-level/topic-1-cell-biology/15-the-origin-of-cells/non-living-synthesis.html
- https://www.windows2universe.org/earth/Atmosphere/overview.html
- http://www.truthinscience.org.uk/content.cfm?id=3161
- http://marinebio.org/oceans/history/
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- https://www.noaa.gov/resource-collections/coral-ecosystems
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- https://www.khanacademy.org/science/biology/ecology/biogeochemical-cycles/a/the-carbon-cycle
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- https://serc.carleton.edu/NAGTWorkshops/sedimentary/images/cross_bedding.html
-