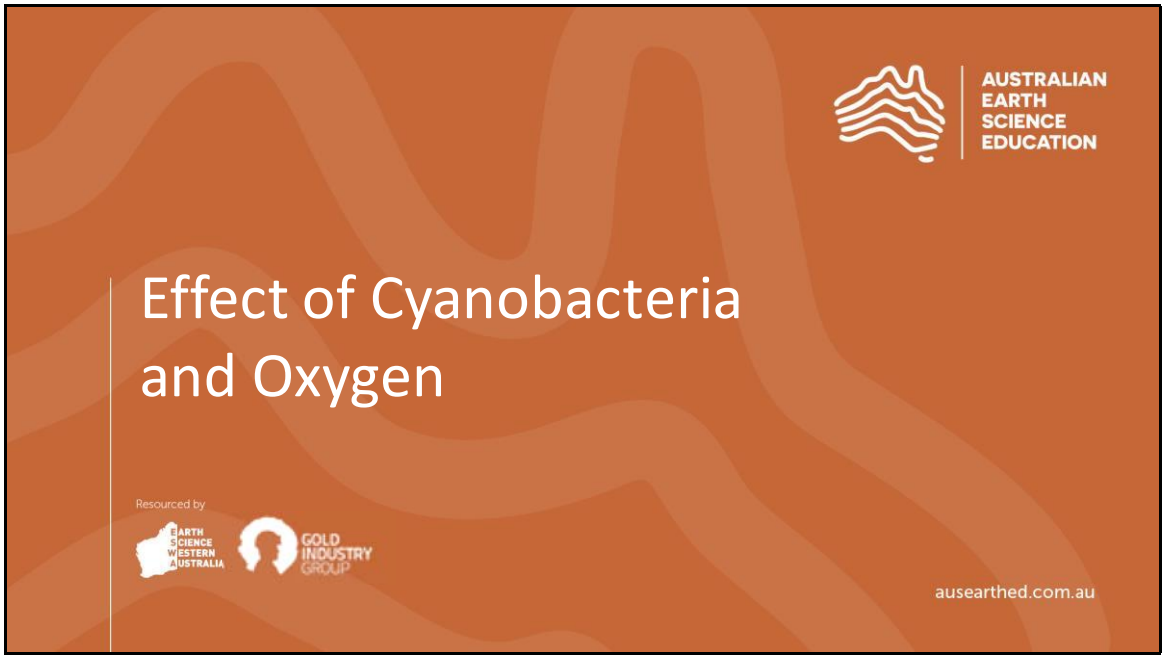
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Effect of Cyanobacteria and Oxygen
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Cover Slide

Cyanobacteria and oxygenic photosynthesis

- Cyanobacteria were the first organisms to evolve oxygenic photosynthesis
- Chloroplasts are captured cyanobacteria (endosymbiosis)

Cyanobacteria (NOAA, public domain)

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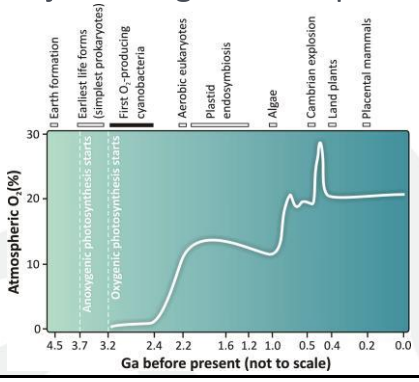
Oxygenic photosynthesis only arose once – in the cyanobacteria.

Algae and plants have captured cyanobacteria via endosymbiosis. Chloroplasts are the captured cyanobacteria.

Great Oxidation Event (GOE)

- The GOE is the rise of atmospheric oxygen to constant low levels for the first time in Earth's history
- This caused major changes in all spheres of Earth



Timeline of oxygenation and events in the history of life. (G and D Shevela 2011, Creative Commons)

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There were brief periods of oxygen production before the GOE, but these were not sustained. They may have been produced by photosynthesis, but there are other options such as photolysis. From the GOE onwards, there has always been at least some oxygen in the atmosphere.

Changes to the biosphere: primary production

- Oxygenic photosynthesis is very efficient (at least 10x more than other types)
- Inputs of carbon dioxide and water are abundant

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Oxygenic photosynthesis is more efficient than other types of photosynthesis and the inputs are common in the environment. This makes it a viable option in a wide variety of early environments including oceans, fresh water and soil.

Changes to the biosphere: mass extinction

- Oxygen was toxic to most microbes
- This led to the first mass extinction

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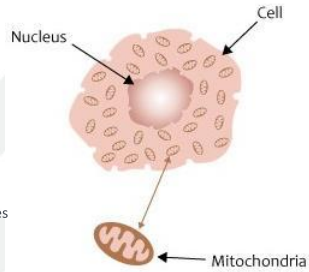
Oxygen was toxic to the microbes of early Earth. Those which did not quickly evolve ways of dealing with oxygen became extinct or were limited to anaerobic habitats. This was, arguably, Earth's first mass extinction.

Changes to the biosphere: aerobic respiration

- Aerobic respiration (using oxygen) arose shortly after the evolution of oxygenic photosynthesis
- Aerobic respiration is much more efficient than anaerobic respiration



Aerobic respiration in human cells takes place in mitochondria (NHS Genomics Education Programme 2014, Creative Commons)

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Genetic analysis indicates that aerobic respiration rose quickly in all lineages of cyanobacteria (including those that do not produce oxygen) after the evolution of oxygenic photosynthesis.
Aerobic respiration is more efficient than anaerobic respiration.
In human cells (shown), aerobic respiration takes place in the mitochondria. Like chloroplasts, these organelles have their own DNA and are considered endosymbionts.

Changes to the geosphere

- Iron oxide deposits on land occur
- Minerals that decompose in oxygen become rare

Red beds of Proterozoic age in lower strata of Grand Canyon (J St John 2007, Creative Commons)

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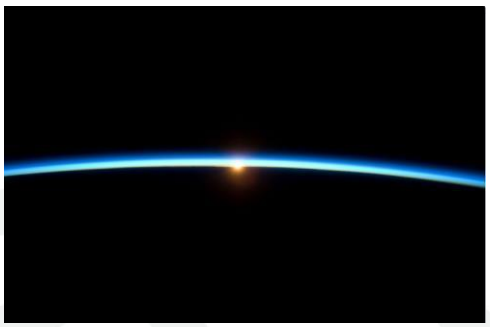
GOE is marked by mineral changes. Iron oxide deposits, like terrestrial redbeds, occur. Minerals that decompose in the presence of oxygen become rare.

Changes to the atmosphere

- Carbon dioxide decreased
- Oxygen increased
- Ozone layer begins to form



Earth's atmosphere and the setting sun (NASA, public domain)

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Carbon dioxide was taken up by photosynthesis. The carbon became part of the biosphere. Oxygen was released into the atmosphere and the ozone layer began to form.

Changes to the hydrosphere

- Decreased carbon dioxide
- Increased oxygen
- Final depletion of dissolved ferrous iron (Fe^{2+})

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Microscopic studies of ancient stromatolites suggests that the microbial mats both trapped sediment and secreted carbonates, just like modern stromatolites.

Other events at the time of the GOE

- Continental crust rises above oceans
- Volcanoes erupt on land
- Modern plate tectonics (subduction) begin

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Prior to this time, continental crust was still weak and thin, covered by shallow seas. As more continental crust was formed and earth cooled, crust rose above the oceans around 2.5 Ga.

Volcanoes on land erupted and released a different mix of gas – more sulfur dioxide rather than hydrogen sulfide.

The cooler and stiffer oceanic lithosphere began to have modern subduction cycles. Plate tectonics as we know it today had begun.


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