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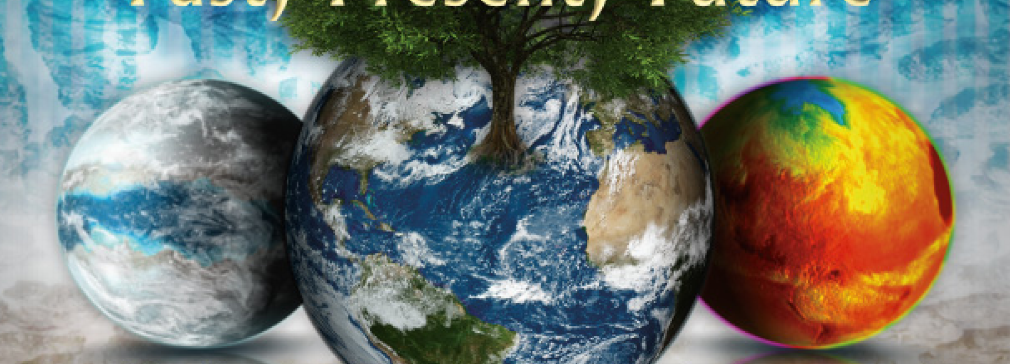
CHANGING PLANET
Past, Present, Future



Series available online and on DVD at BioInteractive.org/changing-planet-past-present-future

EARTH EVOLUTION
The Intersection of Geology and Biology

The Earth is approximately 4.6 billion years old. Over this vast span of time, the planet has changed dramatically from an inhospitable sphere of molten rock to a diverse world rich with life. The world we live in today is the product of complex interactions between life and the environment.

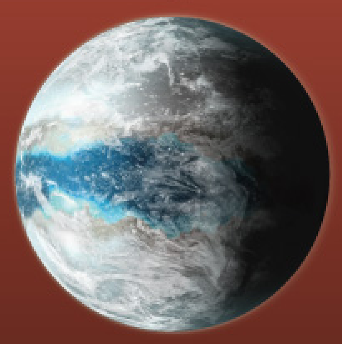
Eons	Eras	Periods
PHANEROZOIC	Cenozoic	Paleogene
	Mesozoic	Cretaceous
		Jurassic
		Triassic
	Paleozoic	Permian
		Carboniferous
		Devonian
		Silurian
		Ordovician
		Cambrian
PROTEROZOIC		Ediacaran
		Cryogenian
ARCHEAN		
HADEAN		

Time scale (millions of years): 0, 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3200, 3400, 3600, 3800, 4000, 4200, 4400, 4600

- Ice Age
- Snowball Earth
- Snowball Earth
- Rodinia breakup
- Supercontinent Rodinia forms

- Early supercontinent (Nuna)

- Snowball Earth



At the beginning and end of the Proterozoic Eon, glaciers extended all the way to the equator. The ice eventually receded as greenhouse gases ejected by volcanoes accumulated in the atmosphere, warming the planet.

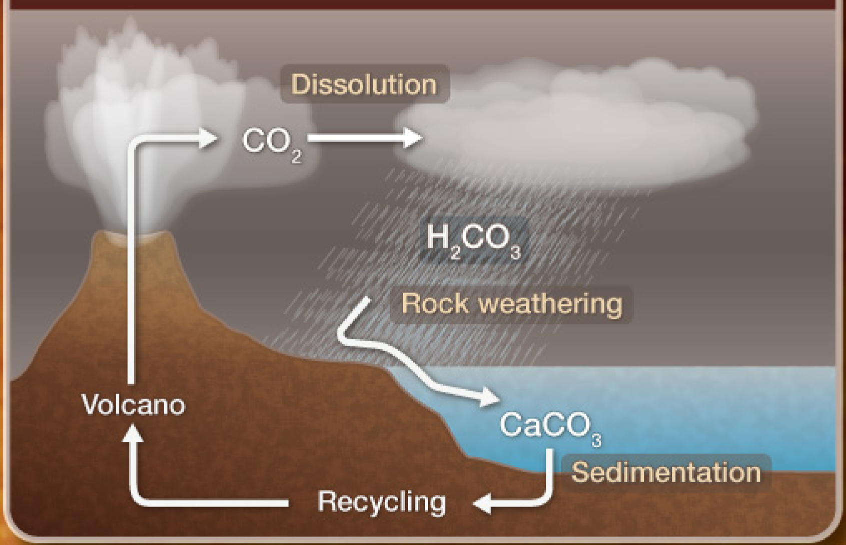
- Earliest evidence for plate tectonic movements

Mass Extinctions

There have been multiple mass extinctions during the course of Earth's history in which dominant organisms were wiped out, opening up new evolutionary possibilities for survivors. The mass extinction at the end of the Cretaceous Period 65 million years ago is thought to have been caused by the impact of a large (11 km) meteorite. Other mass extinctions, however, appear to reflect environmental perturbation caused by Earth processes such as volcanism and climate change.

Geologic Carbon Cycle

Volcanoes release carbon dioxide—a greenhouse gas—from the lithosphere into the atmosphere. Warmer temperatures accelerate rock weathering reactions, which remove carbon dioxide from the atmosphere. This cycle acts as a global thermostat.



Greenhouse Effect

As sunlight warms the Earth, it re-radiates energy back to space. Greenhouse gases absorb this energy, resulting in further warming. Without the greenhouse effect, Earth would be too cold for life, but too much of it can create an inhospitable environment.

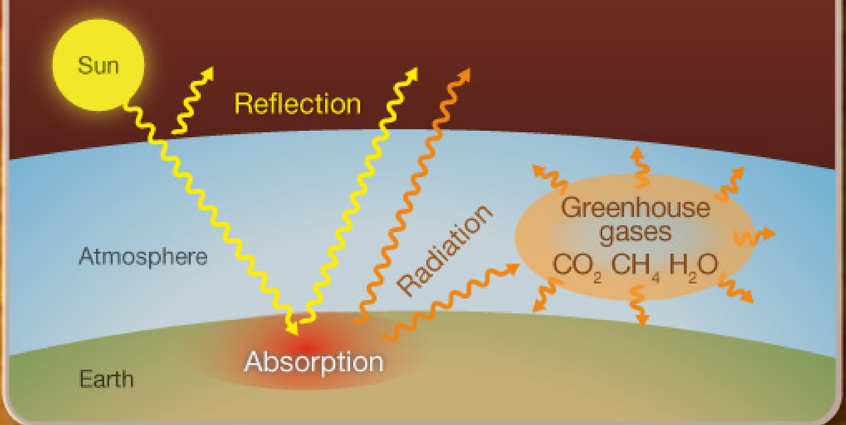
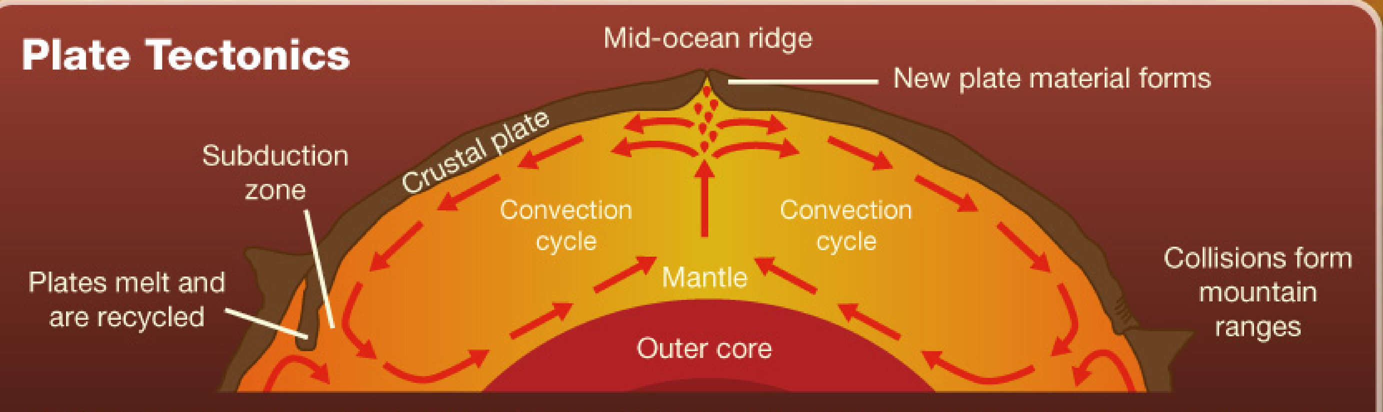


Plate Tectonics



Earth's crust is composed of large plates that move in response to forces generated by convection of material in the underlying mantle. Plate movements have resulted in the formation of supercontinents such as Nuna, Rodinia, and Pangea, at different times in Earth's history.

- Oldest rock

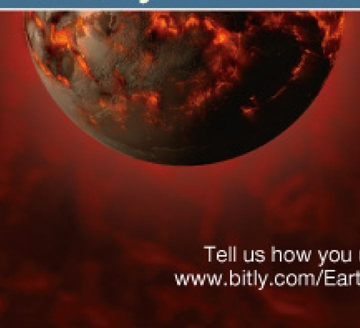
Rock Types 101

Igneous: Form when molten materials cool and harden, either beneath the Earth's surface or in a volcanic eruption.

Sedimentary: Form at the Earth's surface when particles eroded from older rocks accumulate or when minerals from lake, river, or ocean water precipitate.

Metamorphic: Form when existing rocks are changed by heat and pressure.

- Earliest date for liquid water on Earth
- Earth forms by accretion from solar dust cloud



Phylogeny of Main Groups of Organisms

- Genus *Homo* — 0
- Dinosaur extinction; Mammalian dominance
- Permian extinction
- First land vertebrates
- First land plants
- Cambrian explosion
- Ediacaran diversification of large animals

Oxygen and Animal Size

Large active animals require high levels of oxygen. They did not evolve until the Ediacaran and Cambrian Periods, when oxygen rose to near-modern levels.

- Origin of chloroplast by symbiosis
- Oldest eukaryotic fossil

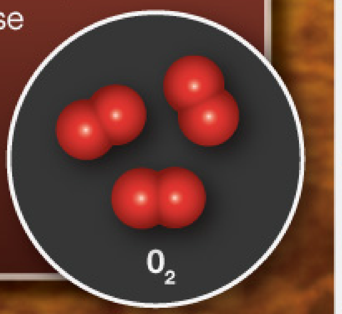
Origin of Eukaryotes

Eukaryotes are thought to have arisen as a result of symbiosis of different prokaryotes. The mitochondrion originated as a bacterium captured by another cell, possibly a member of the Archaea. Chloroplasts arose later by the symbiotic incorporation of cyanobacteria into a eukaryotic host.

- Oxygen first reaches significant (about 1% of current) levels

Oxygenation of the Planet

Oxygen gas was not present in Earth's early atmosphere; it arose as a by-product of oxygenic photosynthesis. Initially, early microorganisms' photosynthetic reactions did not use water and did not release oxygen. Once oxygen-generating organisms evolved, oxygen reacted with dissolved iron and sulfide in the ocean and did not accumulate. After these compounds were oxidized, free oxygen started to accumulate.



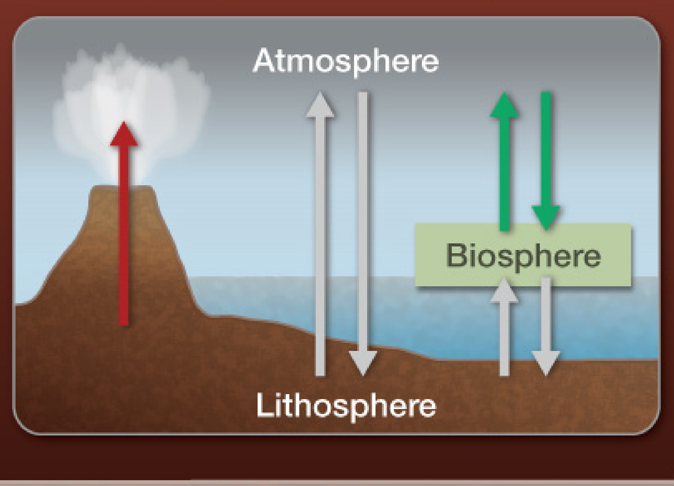
Evidence of Early Photosynthesis

The earliest known stromatolites—layered deposits made by photosynthetic microorganisms—suggest that photosynthesis arose at least 3.5 billion years ago. Today, photosynthesis fuels most ecosystems on Earth, but Earth's earliest biological communities may have been driven by chemosynthesis, gaining energy from chemical reactions to form organic compounds.

- Photosynthesis; Oldest fossils on Earth; Stromatolites
- Oldest chemical signature of life

Life and Chemical Cycling

All life depends on carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphorous. These elements are abundant in the lithosphere and/or atmosphere and cycle between the two. Naturally occurring forms of sulfur and nitrogen cannot be used by living organisms. Early in Earth's history, microorganisms evolved mechanisms to extract these elements from the environment, allowing rapid growth of Earth's ecosystems (biosphere). These microbial mechanisms remain essential to life on Earth—billions of years later.



Time Before Present (millions of years)

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