Principle 4: The ocean makes Earth habitable.

Oxygen Production — A

The accumulation of oxygen in Earth's atmosphere through photosynthesis was necessary for life to develop and be sustained on land.

A1

All oxygen gas came originally from photosynthetic organisms in the ocean.

A2

About 3 billion years ago, cyanobacteria, with the ability to use sunlight, water, and gases to synthesize organic molecules, produced oxygen gas as a waste product.

A3

Until about 2.5 billion years ago, the majority of oxygen gas produced through photosynthesis was consumed in the process of oxidizing reduced compounds, forming vast sedimentary deposits, and changing the chemistry of the ocean and sediments.

A4

Dissolved oxygen started to accumulate in the ocean when much of the free reduced compounds were oxidized.

A5

The accumulation of oxygen in the ocean allowed for the development of aerobic bacteria that used oxygen in a new biochemical pathway, producing ATP more efficiently.

A6

This energy efficient biological pathway that developed in aerobic bacteria, along with oxygen in the ocean, allowed for the development of complex oceanic eukaryotic cells about 2 billion years ago.

A7

Between 2.3 and 2.4 billion years ago, the oxygen concentration in the ocean was high enough that it started to escape and accumulate in the atmosphere, where it formed ozone, blocking much of the UV radiation from reaching Earth's surface.

A8

Multicellular life, which requires high oxygen levels, developed about 1 billion years ago. By 550 million years ago, free oxygen and ozone levels were high enough to allow the development of terrestrial organisms.

A9

Photosynthesis produces oxygen gas and is balanced by a loss of oxygen gas through respiration, decay of organisms, and oxidation of exposed minerals. The burial of some dead organisms in the sea floor sediments prevents their decay and keeps atmospheric oxygen near 20%.

A10

There is no steady state of oxygen gas on geological time scales. Oxygen and carbon dioxide concentrations in the atmosphere change within relatively wide limits, controlled by a combination of biological, geological, and chemical processes.

Origins of Life — B

Life started in the ocean and the earliest evidence of life is found in ancient ocean sediments.

B1

The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.

B2

The fossil record of ancient lifeforms provides evidence for the theory of evolution and the important role the ocean played in the evolution of life on Earth.

B3

The first multicellular organisms to invade land from the ocean were plants, followed by arthropods. Later, organisms, such as lobe-finned fishes, started moving between the shallows and the land. These fishes evolved into amphibians.

B4

One dominant theory about the evolution of early lifeforms (prokaryotes) is that they evolved about 3.5 billion years ago near a hydrothermal vent in the ocean.

B5

Most living organisms, including all animals, plants, fungi, and protists, are eukaryotes that evolved from prokaryotes.