Water and Life

How large is the earth?
- Radius: 3986 mi (4000 mi)
- Diameter: 7973 mi (8000 mi)
- Circumference: 25,048 mi (25,000 mi)

Volume of Water:
- 400 billion billion gallons
- 326 million mi³

Earliest Evidence of Liquid Water on Earth ~ 4.3 bya
Western Australia, 2001

Zircon Crystals
Earth's oldest terrestrial materials
Pillow Lavas

3.5 bya

Basaltic Extrusive Rock

Sources of Earth’s Water

Earth’s Mantle

Asteroids

Comets

Setting the stage for the evolution of life

Water is an essential precursor to life.
Water and Life

The most abundant substance in living systems

70%

- Plants ~ 80%
- New born baby ~ 77%
- Grown man ~ 65%
- Grown woman ~ 58%
- The elderly ~ 50%

A loss of just 5 percent of the body's total water will cause the mouth to go dry, the surface of the skin to shrink, and may even cause hallucinations.

A loss of more than 12 - 15 percent total body fluid would be fatal.

The longest anyone has ever survived without water is 13 days.

Water Loss

- 15 percent of human water loss is through respiration
- 20 percent is lost through perspiration
- 65 percent is lost by excretion

Water and Life

Water is an ideal medium for life processes.

1. Retains heat, moderates temperature
2. Excellent solvent: transports nutrients, life compounds
3. Participates in biochemical reactions
Water and Life’s Beginnings

Living organisms consist of assemblages of similar complex carbon compounds (organic) and require water to develop.

• To grow and develop, organisms must assemble complex carbon compounds from external sources of carbon.
• Assembling complex carbon compounds requires energy and reaction with water.
• Metabolism and reproduction are controlled by proteins. Protein synthesis requires reaction with water.

Water, Carbon, and Life

Water, Life, and the Earliest Organisms
Early Organisms and Conditions on Earth

Ammonium
Carbon Dioxide
Hydrogen
Helium
Water Vapor

What's missing?
Oxygen

The Earliest Organisms

Anaerobic
live in low-oxygen environments
or in the absence of oxygen.

Autotrophic
Self-feeding. Cannot consume
other organisms for energy.

Two Types of Autotrophs

Photoautotroph
Use light energy to assemble complex
carbon compounds (organic) from simpler
carbon-containing molecules (CO₂)

Chemoautotroph
Use energy from chemical reactions
to assemble complex carbon
compounds (organic) from simpler
carbon-containing molecules
**Photoautotroph**

A photoautotroph is an organism that assembles complex organic compounds from simple carbon-containing molecules using energy from light.

- **Photo = light**
- **Complex organic compounds** (initially sugars $C_6H_{12}O_6$)
- **Simple carbon molecule**: $CO_2$

**Plants**
**Photosynthetic Bacteria**

**Chemoautotroph**

A chemoautotroph is an organism that produces complex organic compounds from simple carbon-containing molecules using energy from chemical reactions.

- **Energy from Chemical Reactions**
  - Zinc/manganese
  - Sulfur/potassium nitrate

**The Earliest Organisms: Chemoautotrophs**

A chemoautotroph is an organism that produces complex organic compounds from simple carbon-containing molecules using energy from chemical reactions.

- **Chemical Reactants (energy)**
  - Iron
  - Sulfur

- **Simple inorganic molecule**: $CO_2$

- **Complex organic compounds**
Evidence for Earliest Organisms

**Chemoautotrophs**
Embedded in the lava are numerous tubular structures left behind by ancient microbes.

- Tubes contain carbon that represents organic material left behind by early organisms.
- ~ 3.5 bya

**Photoautotrophs**
- **2.5 – 3.0 bya**
- **Cyanobacteria** (Blue-green algae)
- Photosynthetic
  - Fix carbon dioxide into complex organic compounds.
  - $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
  - (Simplified)
  - Removed carbon dioxide
  - Production of oxygen

**Stromatolites**
- The oldest *macroscopic* evidence of life on Earth, at least 2.5 billion years old
- Colonies of Photosynthetic Cyanobacteria
- Turfs
Stromatolites

Cyanobacteria colonies

Effect? Produced billions of tons of O₂
Increase in atmospheric O₂?

Little Alteration of the Earth’s Atmosphere

Ammonium
Carbon Dioxide
Hydrogen
Helium
Water Vapor
Oxygen = 0.21%

Photosynthesis

6CO₂ + 6H₂O → C₆H₁₂O₆ + 6O₂

Billions of tons of oxygen

Iron

Does not dissolve in water: insoluble

Iron oxide
In the absence of oxygen, iron is easily dissolved in water.

$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$$

When oxygen is present it quickly combines with iron to form compounds that are not easily dissolved in water.

Dissolved iron $+$ oxygen $\rightarrow$ solid iron

Photosynthesis produces oxygen

Between 1.8 – 2.5 bya

Banded Iron Formations

Iron $+$ oxygen $\rightarrow$ Fe$_3$O$_4$ (solid)

Deposits contain 20 times the oxygen of the atmosphere.

The source of all iron that is mined today

End ~1.8 bya
Emergence of more complex cells
Multicellular Organisms
Increased complexity/diversity of organisms

Diversification of Aquatic Life
• all modern phyla of animals develop
• first vertebrates emerge
• fishes diversify

480-400 Mya - first land plants and animals arise

Why did it take so long?

Water Screens Out Ultraviolet Radiation
~ 500 million years ago

Higher Oxygen Levels
Ozone Layer

The ozone layer screens out harmful UV radiation

Terrestrial Life
First land plants ~480 mya

Carboniferous Period
About 350 million years ago

"the age of swamps and coal"
245 mya – 65 mya

Age of Reptiles

Warm
Wet
Productive

Subsequent Timeline

Reptiles  ~ 245 million years ago
Mammals  ~65 million years ago
Primates  ~30 million years ago
Pre-humans ~5-8 million years ago
Homo sapiens ~200,000 years ago