Lecture 3
Introduction to Planet “Earth”

Overview

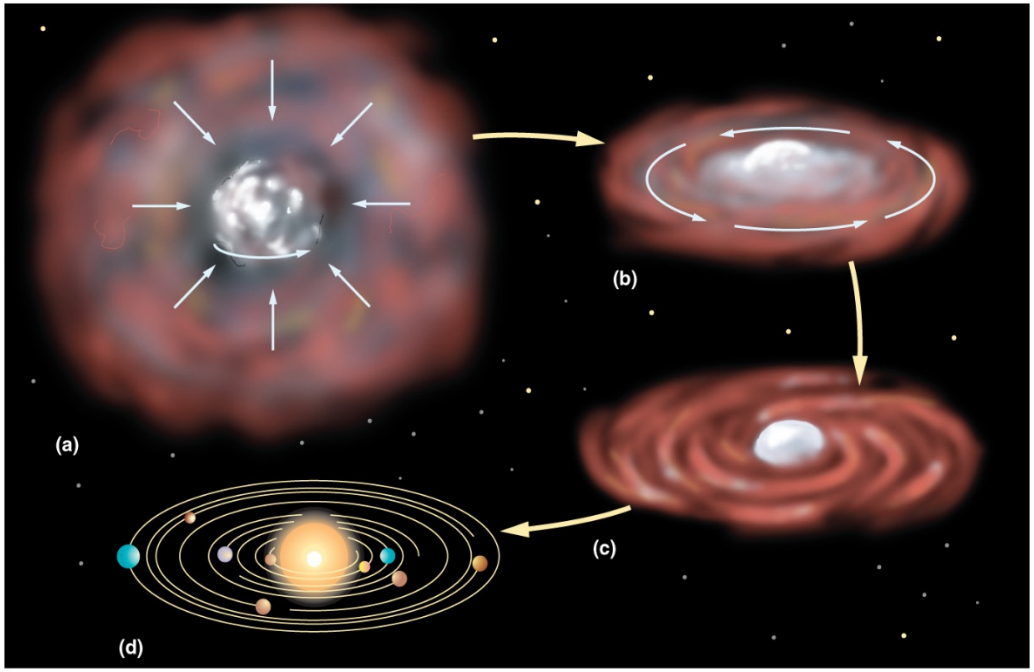
- The world ocean is the most prominent feature on Earth.
- Oceans cover 70.8% of Earth's surface.
- The origin and development of life on Earth is connected to the ocean.
- The oceans have a long history on Earth.

Formation of Earth and the Solar System

- Nebular hypothesis – all bodies in the solar system formed 5 BY ago from nebula
  - Nebula = cloud of gases and space dust
    - Mainly hydrogen and helium

Nebular Hypothesis

- Gravity concentrates material at center of cloud (Sun)
- Protoplanets form from smaller concentrations of matter (eddies)



Protoearth

- Larger than Earth today (1000 times greater and 500 times massive)
- No ocean , no earth
- Homogeneous composition
- Bombarded by meteorites
  - Moon formed from collision with large asteroid

Protoearth

- Radioactive heat
  - Spontaneous disintegration of atoms
  - Fusion reactions
- Heat from contraction (protoplanet shrinks due to gravity) and radioactive decay
- Protoearth partially melts
- Proto-Earth trapped radioactive materials deep inside and the fusion reactions released heat, making the new Earth something of a warm-blooded planet. The reactions melted the material at its core.

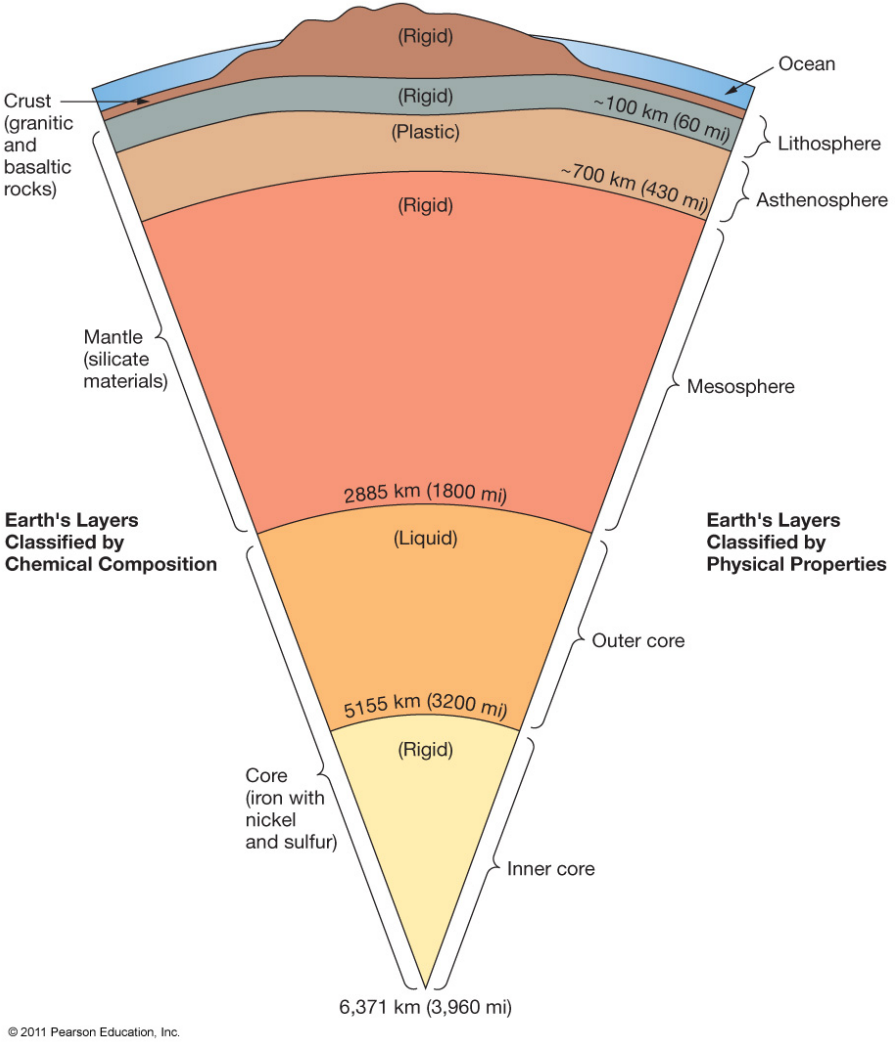
Density Stratification

- Strat (=layer) + fication (=making)
- High density = heavy for its size
- Early Earth experienced gravitational separation.
  - High density materials (Iron and Nickel) settled in core.
  - Less dense materials formed concentric spheres around core.

Earth's Internal Structure

Layers defined by

- Chemical composition
- Physical properties
- Astheno – means "weak" or "soft"



Layers by Chemical Composition

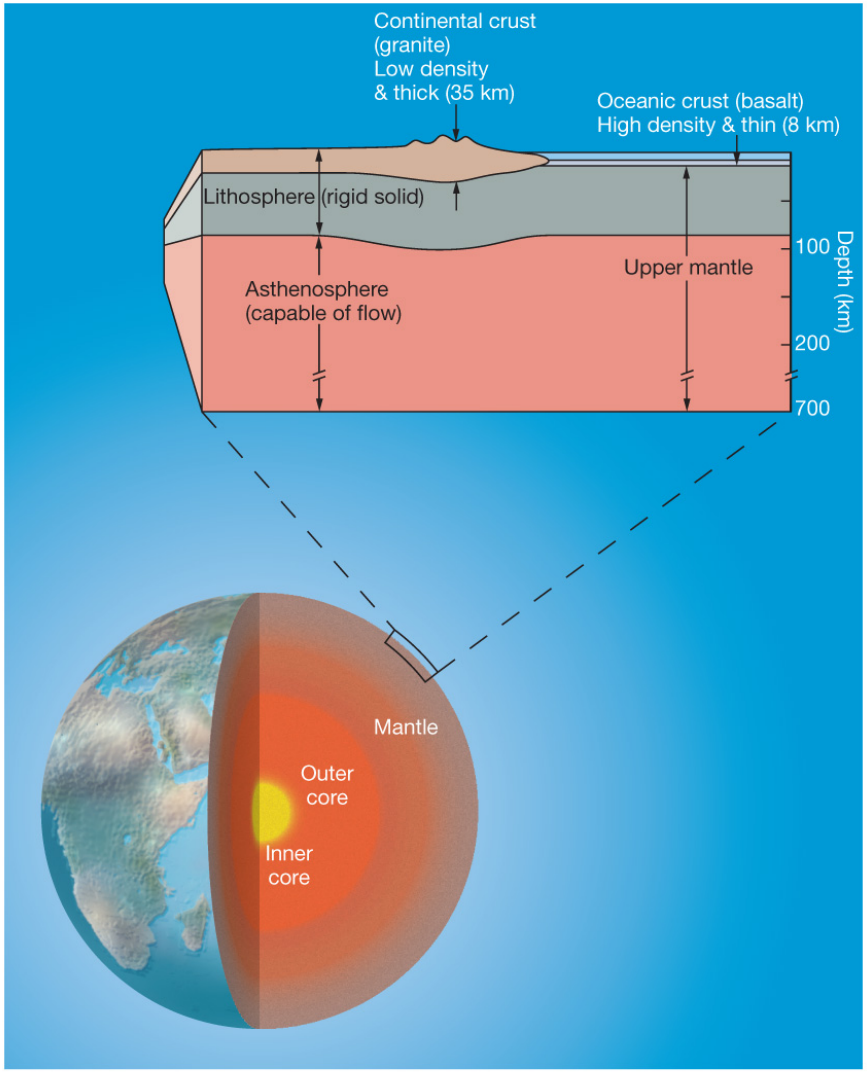
- Crust
  - Low-density, mainly silicate minerals
- Mantle
  - Mainly iron (Fe) and magnesium (Mg) silicate minerals
- Core
  - High-density, mainly iron (Fe) and nickel (Ni)

Layers by Physical Properties

- Lithosphere
- Asthenosphere
- Mesosphere
- Outer core
- Inner core

Lithosphere

- Cool, rigid shell
- Includes crust and upper mantle
- About 100 km (60 miles) thick



© 2011 Pearson Education, Inc.

Continental vs. Oceanic Crust

TABLE 1.1 COMPARING OCEANIC AND CONTINENTAL CRUST

	Oceanic crust	Continental crust
Main rock type	Basalt (dark-colored igneous rock)	Granite (light-colored igneous rock)
Density (grams per cubic centimeter)	3.0	2.7
Average thickness	8 kilometers (5 miles)	35 kilometers (22 miles)

© 2011 Pearson Education, Inc.

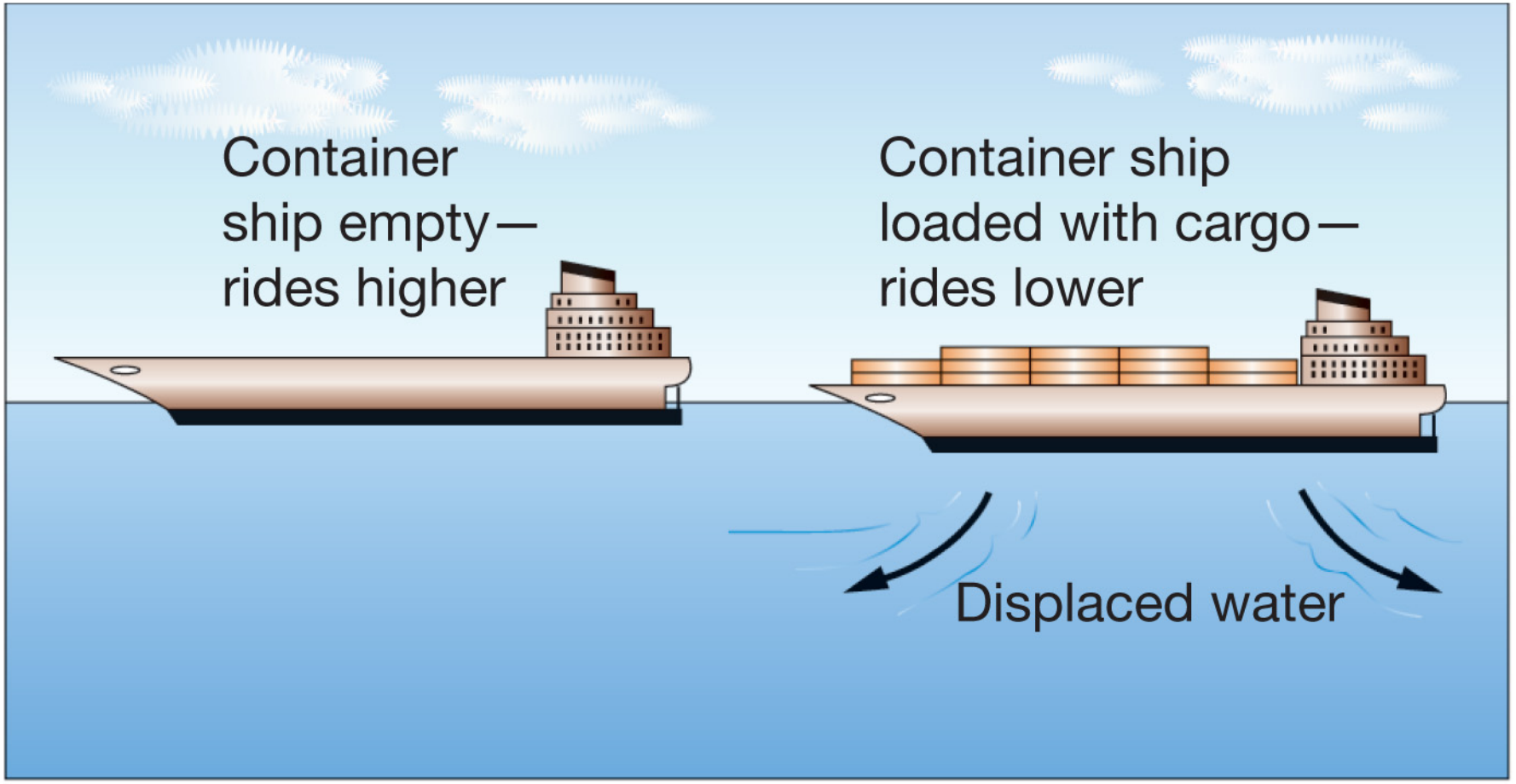
Asthenosphere

- Relatively hot, plastic
- Flows with high viscosity
  - Important for movement of lithospheric plates
- Base of lithosphere to about 700 km (430 miles) deep

Isostatic Adjustment

- Vertical movement of Earth's crust
- Buoyancy of lithosphere on asthenosphere
  - Less dense continental crust floats higher than denser oceanic crust
- Isostatic rebound – rising of crust formerly weighed down by glacier ice

Isostatic Adjustment



Origin of Earth's Atmosphere

- Outgassing – occurred during density stratification
  - Water vapor
  - Carbon dioxide
  - Hydrogen
  - Other gases
- Earth's early atmosphere different from today

Origin of Earth's Oceans

- Outgassed water vapor fell as rain.
- The first permanent oceans formed 4 billion years ago.
- Salinity developed from dissolved rock elements.
  - Early acidic rain dissolved more crustal minerals than today.

Formation of the Earth's Ocean and Atmosphere

1) The Origins of Earth's Atmosphere and Ocean are Closely Tied Together

2) The Composition of the Atmosphere Has Greatly Changed Over the Last Four Billion Years

3) The Composition of Ocean Initially Changed Over the First Billion Years But Has Since Remained Stable

Evolution of Earth's Atmosphere

Three Stages

1) Primordial Atmosphere ???

- ✓ Hydrogen and helium from original condensed nebula
- ✓ Probably stripped away by early solar wind and heating

2) Secondary Atmosphere

- ✓ Volcanic outgassing of volatiles from inside planet
- ✓ Primarily water and carbon dioxide with sulphuric and hydrochloric acid, and methane
- ✓ No free oxygen – a nasty, poisonous, acidic mixture

3) Modern Atmosphere

- ✓ Modification of earlier atmosphere by life processes
- ✓ Removal of carbon dioxide and enrichment of free oxygen

Original Sources of Ocean Water

Two Primary Sources

1) **Volcanic Outgassing**
   - ✓ Majority Amount of H20

2) **Comet Impacts**
   - ✓ Minority Amount of H20

Comet Strikes

Outgassing of Interior

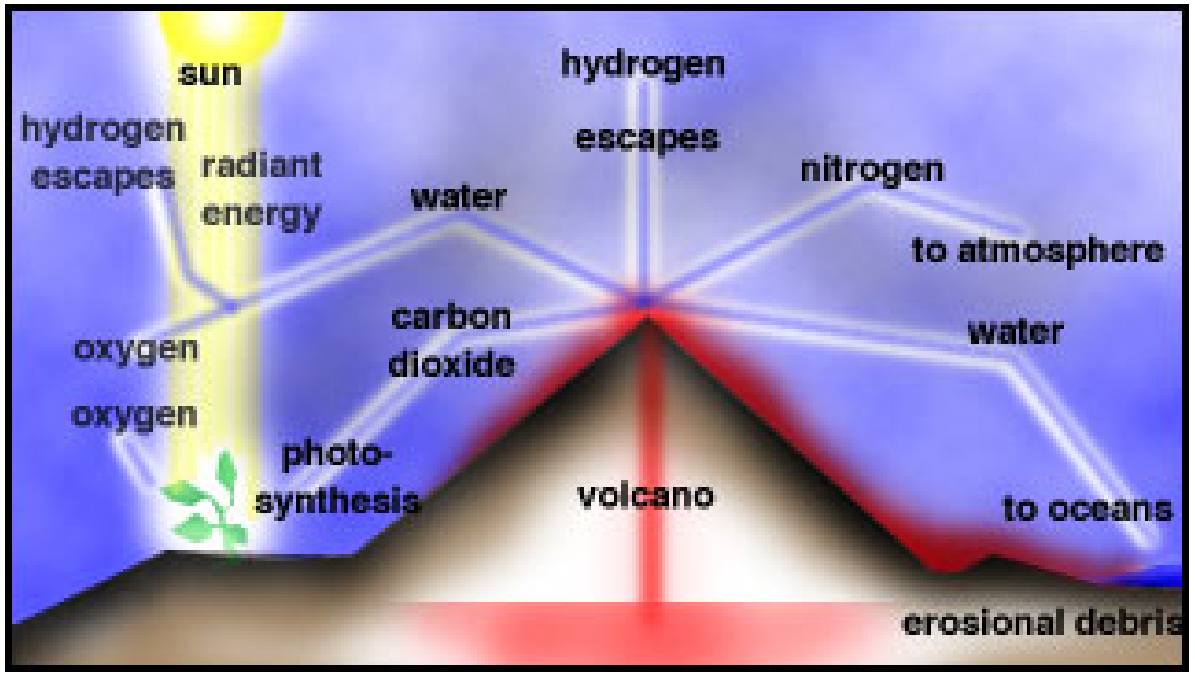
Water initially collected from these two sources as part of a thick, dense atmosphere that later condensed and precipitated into surface waters

Water from Outgassing

Majority Primary Source = Volcanic Outgassing

H_20	CO_2	SO_2	H_2S	HCl
95	1.1	1.5	0.07	0.006
96	1.9	2.3	0.08	0.004
97	1.1	1.5	0.07	0.006

Composition of volcanic gases for three volcanoes



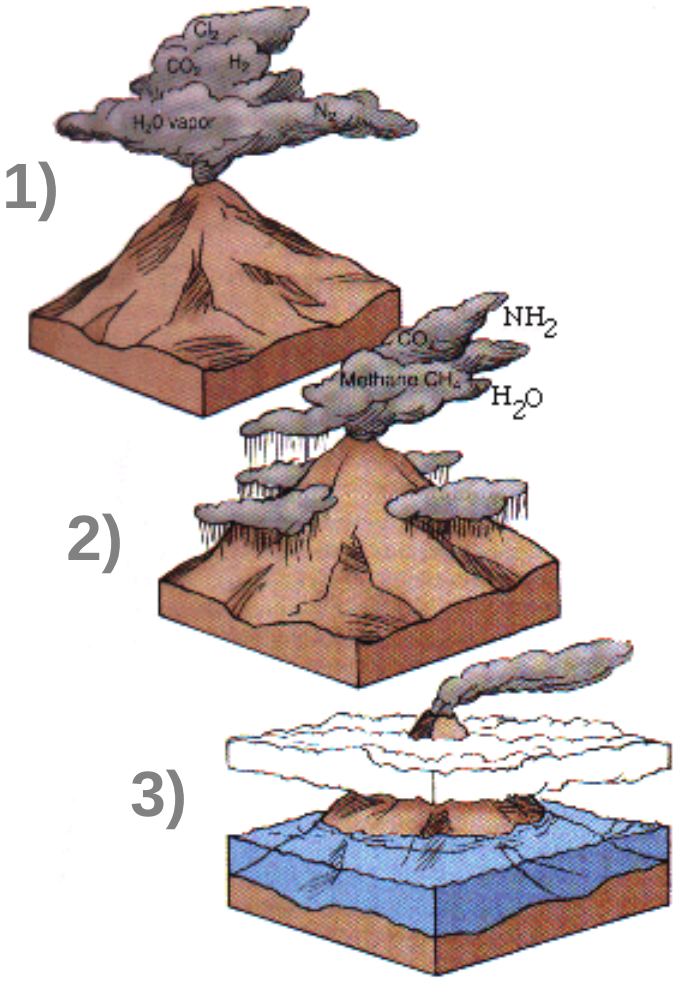
Formation of Our Ocean

Three Phase History

1) Initially there was only water vapor in atmosphere – Air and ground surface too hot for liquid

2) Cooling of atmosphere led to condensation and rain – Ground surface still too hot for pooling

3) Further cooling of ground surface finally led to the accumulation of liquid water on surface – Ocean formed by 4 billion years ago



Why the Ocean not dried up?

- Earth's seasonally similar distance from the Sun
- Earth's rotation
- The atmosphere protects the ocean, insulating around the Earth, blocking both incoming solar energy and escaping re-radiated energy.

Source of Ocean Water

Source of Ocean Water

Studies have shown that the material brought to Earth's surface by volcanoes comes from the lower crust or the upper mantle. Let's start our examination of the source of ocean water by determining the mass of Earth's mantle.

Earth's mantle has a volume of 1.0×10^{27} cubic centimeters and an average density of 4.5 grams per cubic centimeter. The general equation is

$$\text{volume} \times \text{density} = \text{mass} \qquad (2\text{–}1)$$

To determine the mass of material in the mantle, we plug values into Equation (2–1):

$$(1.0 \times 10^{27}\ \text{cm}^3) \times (4.5\ \text{g/cm}^3) = 4.5 \times 10^{27}\ \text{grams} \qquad (2\text{–}2)$$

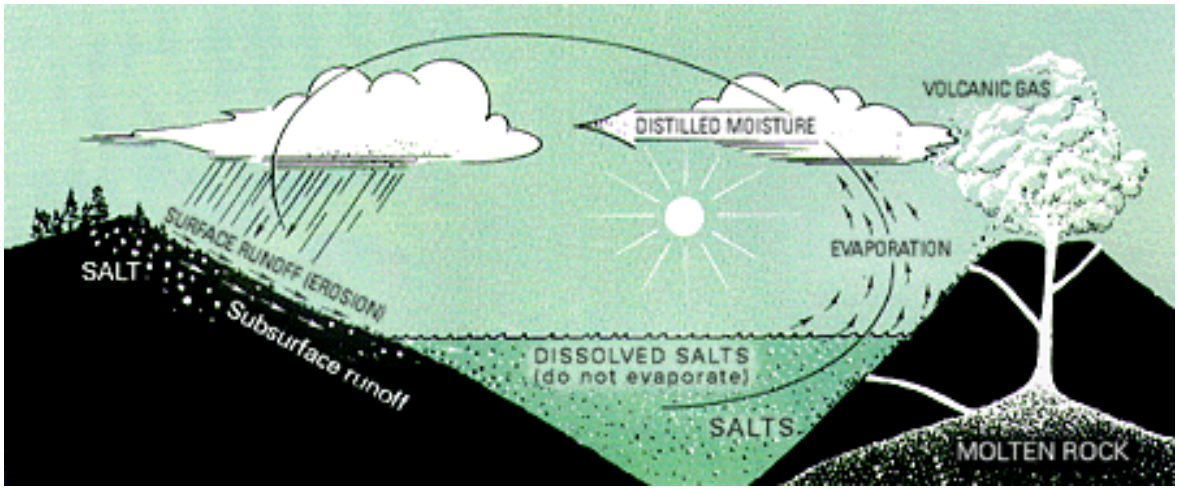
The same method can be used to determine the mass of water in the present-day oceans.

If all of the ocean's water came from the mantle, how much mass has been lost from the mantle? To answer this, we need to compare the mass of the ocean to the mass of the mantle before water loss (which equals present-day mantle mass plus the mass of ocean water). We calculate:

$$\frac{1.4 \times 10^{24}\ \text{g}}{(4500 \times 10^{24}\ \text{g}) + (1.4 \times 10^{24}\ \text{g})} = 0.00031 \textit{ or } 0.031\% \qquad (2\text{–}3)$$

Therefore, the mantle would need to have lost only 0.031% of its mass as water to produce Earth's oceans.

Sources of salts in the Ocean



- Physical weathering - breaks down rocks
- Chemical weathering - release elements contained in the rock by dissolving them
- Volcanic gases emitted into the atmosphere – dissolved in water later

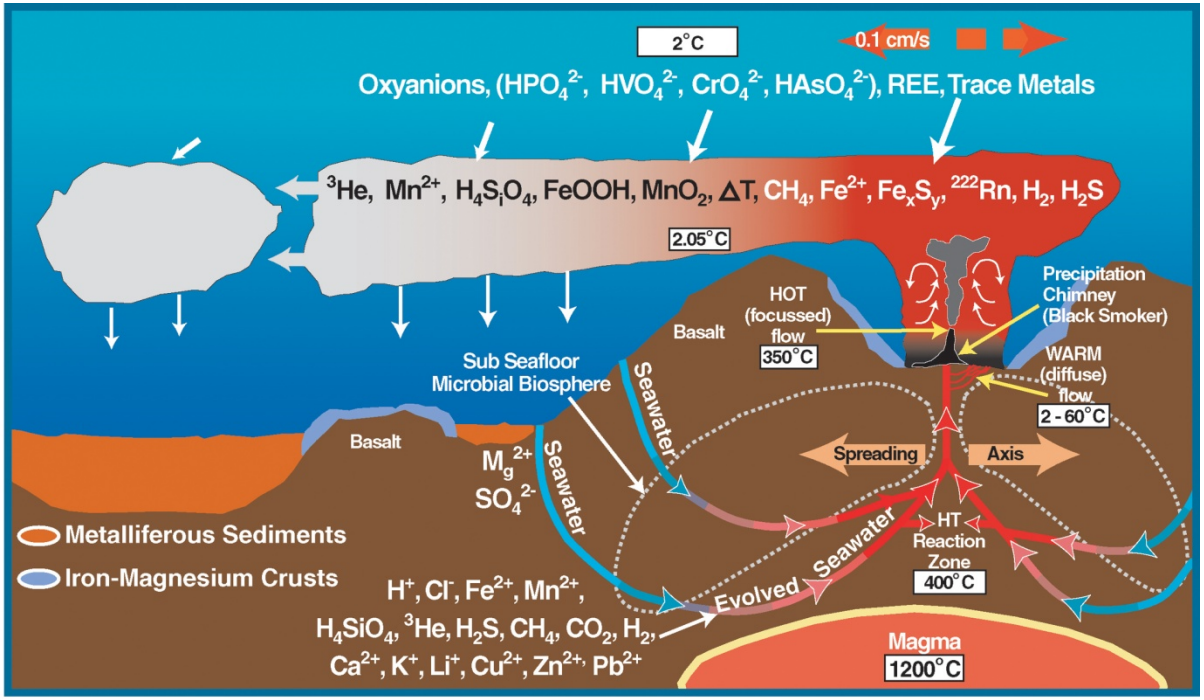
Life's Possible Ocean Origins

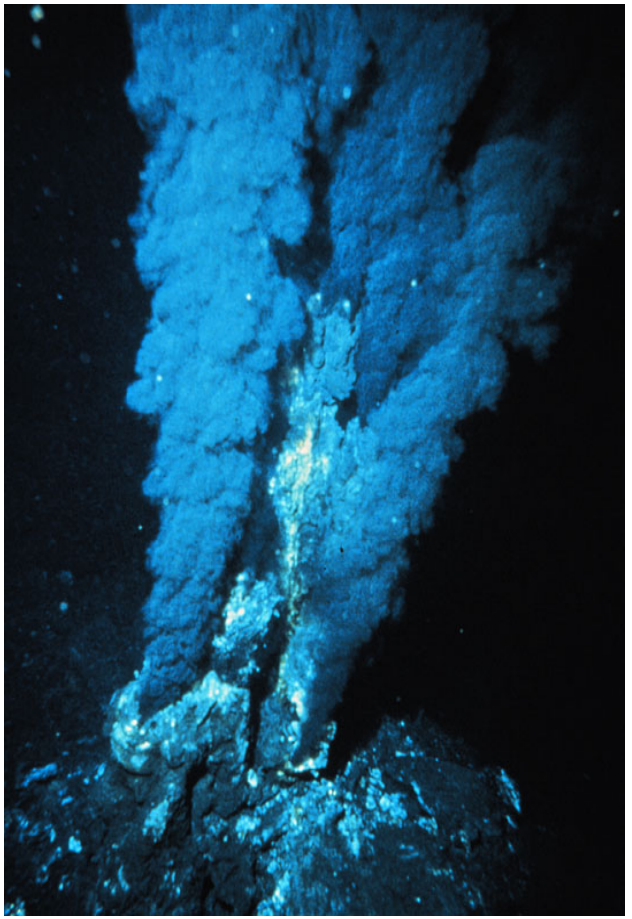
- Earth's earliest known life forms are 3.5-billion-year-old bacteria fossilized in ocean rocks.
- These are the building blocks for life on early Earth.
- There is no direct evidence of early Earth's environment.

Most Likely Cradle [kreyd-l] for Life on Earth?

Deep Sea Hydrothermal Vents?

- Warm, water-rich environment
- Chemical-rich volcanic fluids
- Protected from harsh surface





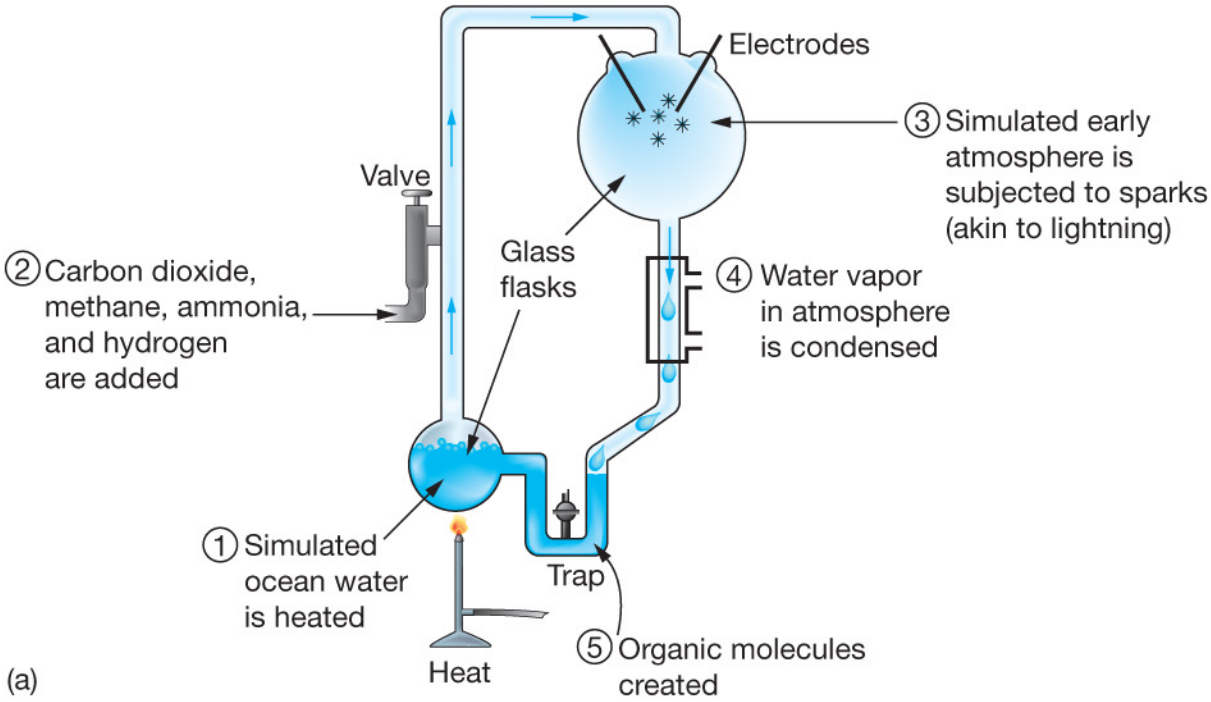
Oxygen

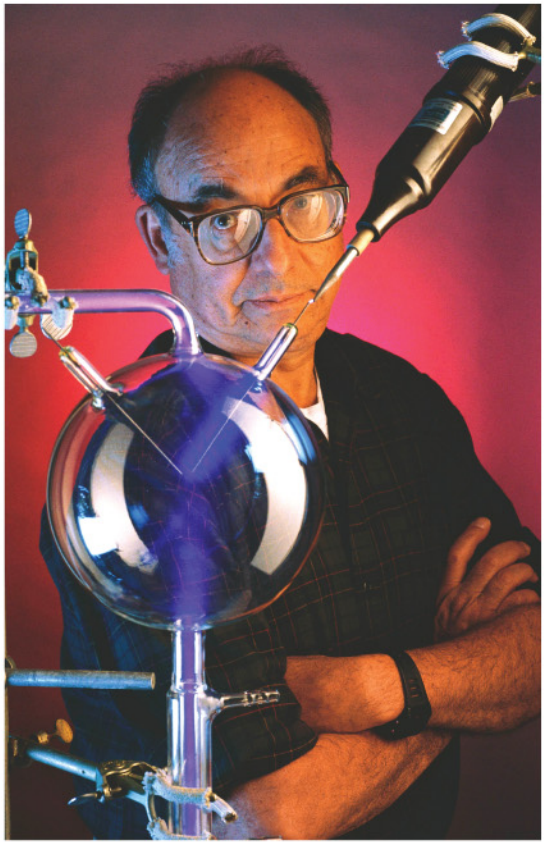
- Humans require O_2.
- Ozone (O_3) protects from ultraviolet radiation.
- Early Earth had little free oxygen.
- The lack of ozone may have helped originate life.

Stanley Miller's Experiment

- Organic molecules formed by ultraviolet light, electrical spark (lightning), and a mixture of water, carbon dioxide, hydrogen, methane, and ammonia

Stanley Miller and his Experiment (1952)




(b)

Evolution and Natural Selection

- Organisms adapt and change through time.
- Advantageous traits are naturally selected.
- Traits are passed to the next generation.
- Organisms adapt to environments.
- Organisms can modify environments.

Plants and Animals Evolve

- Heterotrophs
  - Very earliest life
  - Require external food supply
- Autotrophs
  - Evolved later
  - Manufacture own food supply

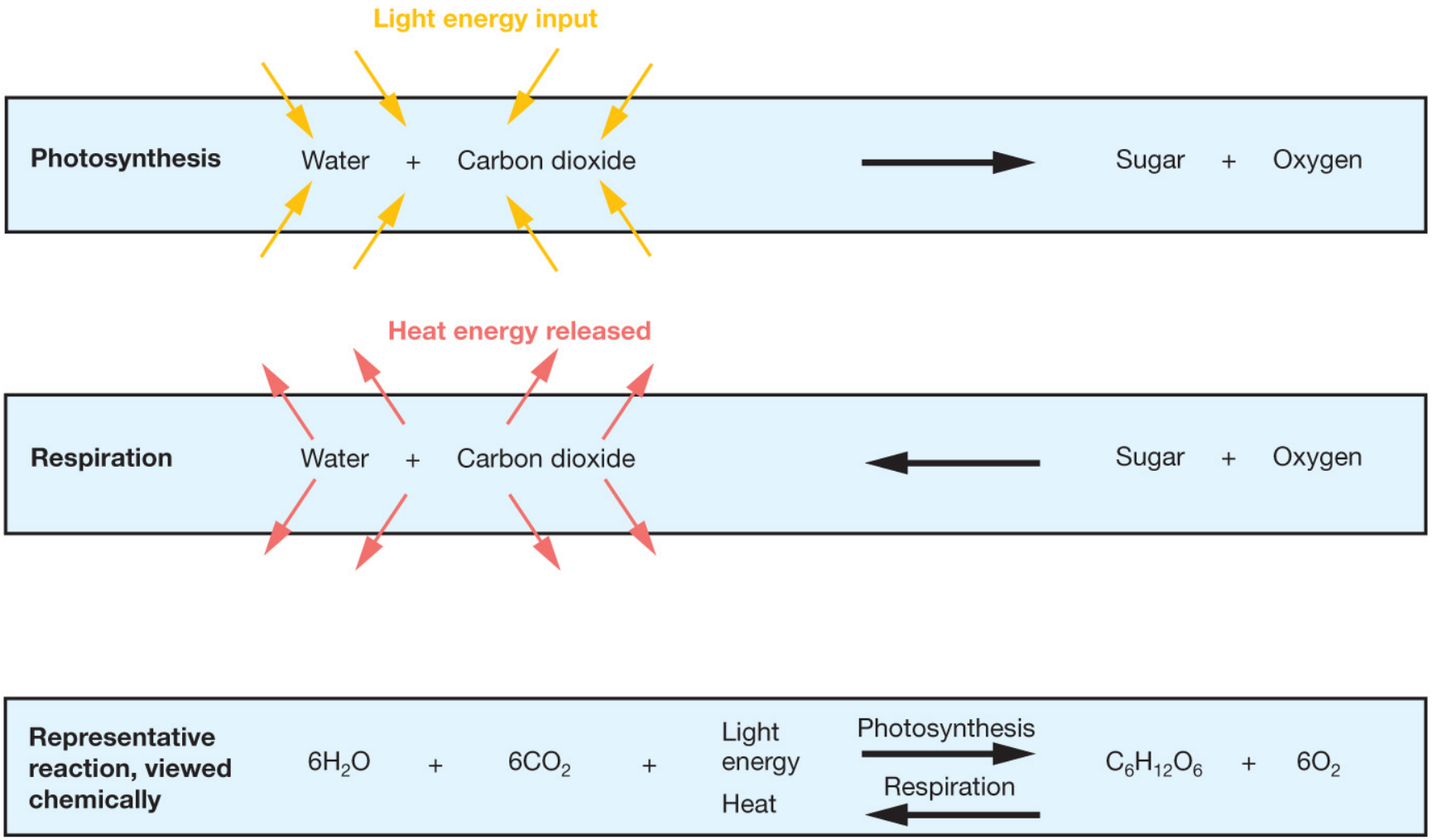
First Autotrophs

- Probably similar to modern anaerobic bacteria
  - Survive without oxygen
- Chemosynthesis from chemicals at deep hydrothermal vents
- Supports idea of life's origins on deep ocean floor in absence of light

Photosynthesis and Respiration

- Complex autotrophs developed chlorophyll.
- This allowed the use of the Sun for photosynthesis.
- Cellular respiration

Photosynthesis and Respiration



© 2011 Pearson Education, Inc.

Great Oxidation Event

- 2.45 billion years ago
- Increased oxygen and ozone eliminated the anaerobe food supply.
- Light and oxygen kill anaerobes.
- Cyanobacteria adapted and thrived.

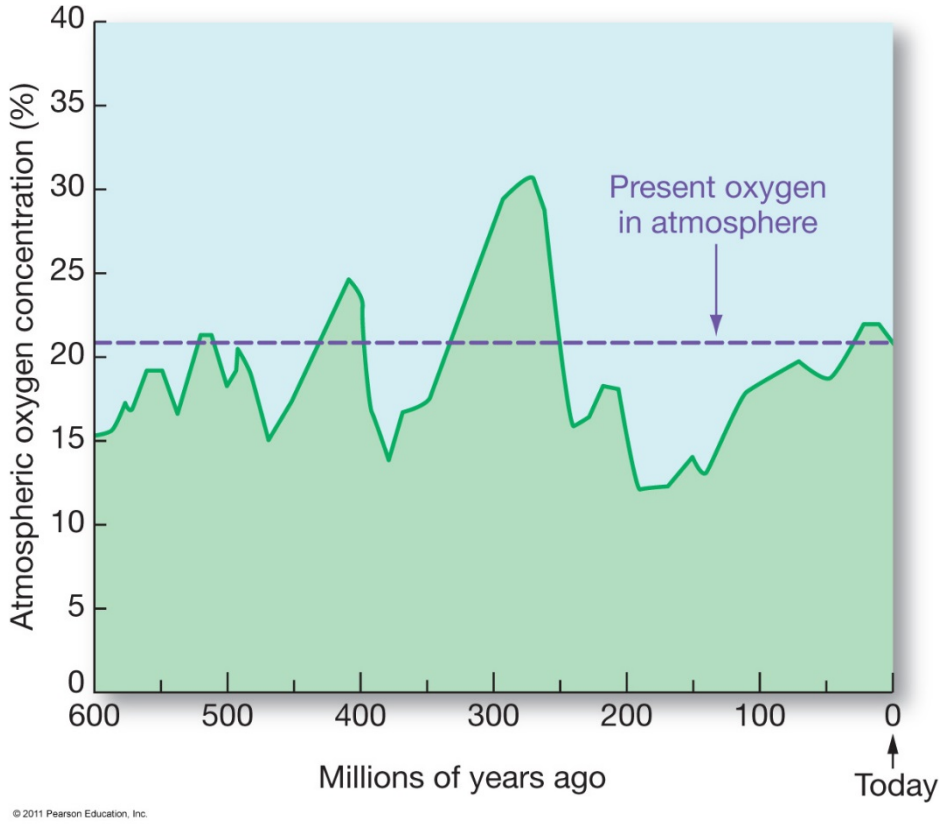
The Great Oxygenation Event (GOE) was the biologically induced appearance of dioxygen (O_2) in Earth's atmosphere. Geological, isotopic, and chemical evidence suggest that this major environmental change happened around 2.3 billion years ago (2.3 Ga).

Cyanobacteria, which appeared about 200 million years before the GOE, began producing oxygen by photosynthesis. Before the GOE, any free oxygen they produced was chemically captured by dissolved iron or organic matter. The GOE was the point when these oxygen sinks became saturated and could not capture all of the oxygen that was produced by cyanobacterial photosynthesis. After the GOE, the excess free oxygen started to accumulate in the atmosphere.

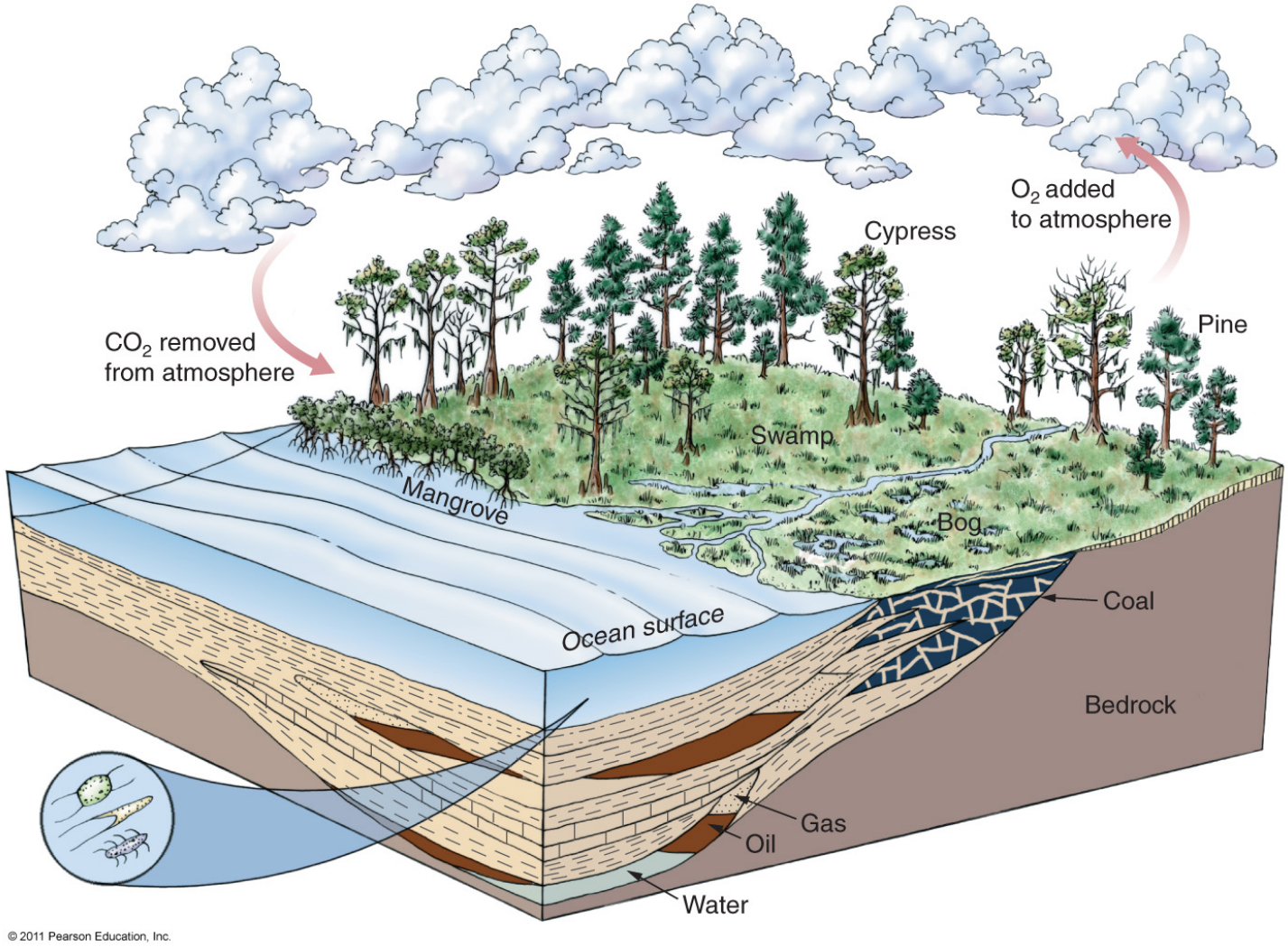
Free oxygen is toxic to obligate anaerobic organisms, and the rising concentrations may have wiped out most of the Earth's anaerobic inhabitants at the time. Cyanobacteria were therefore responsible for one of the most significant extinction events in Earth's history.

Changes to Earth's Atmosphere

- Photosynthetic organisms are responsible for life as we know it today.
- Reduce CO_2, increase O_2 to 21%
- High oxygen = biodiversity increase
- Low oxygen associated with extinction events



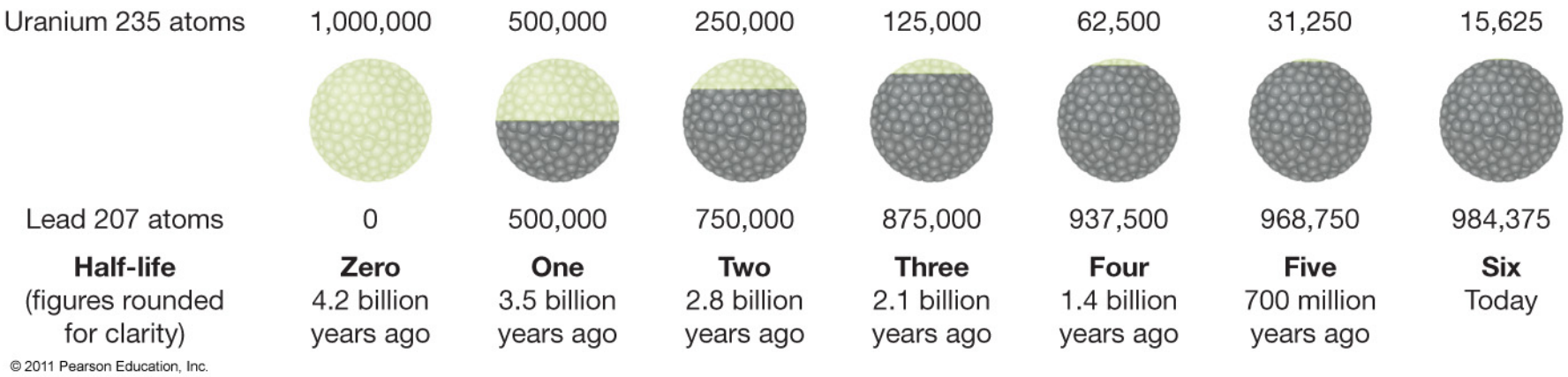
Plants and Earth's Environment



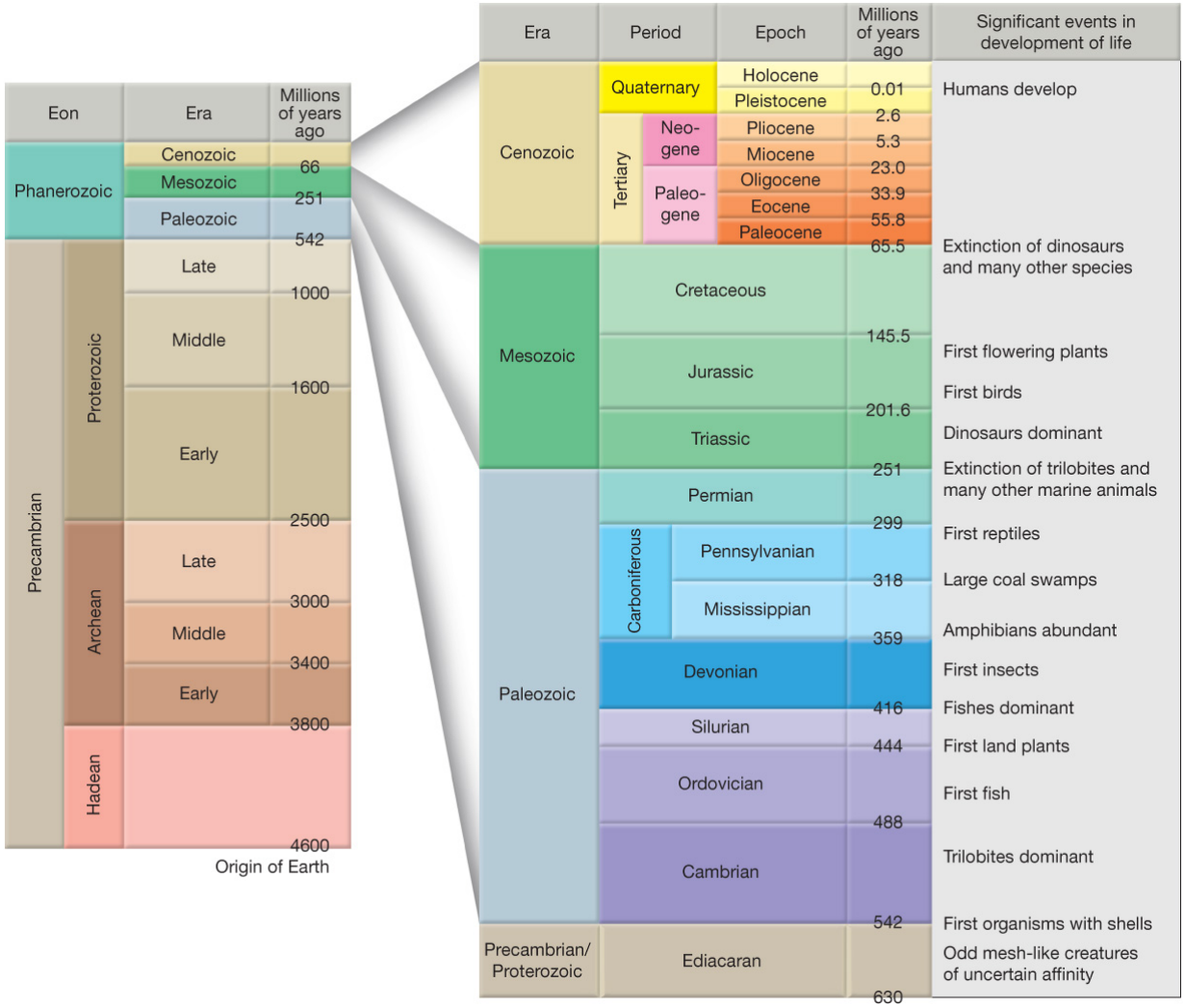
Age of Earth

- Radiometric age dating
  - Spontaneous change/decay
  - Half-life
- Earth is about 4.6 billion years old.

Radioactive Decay



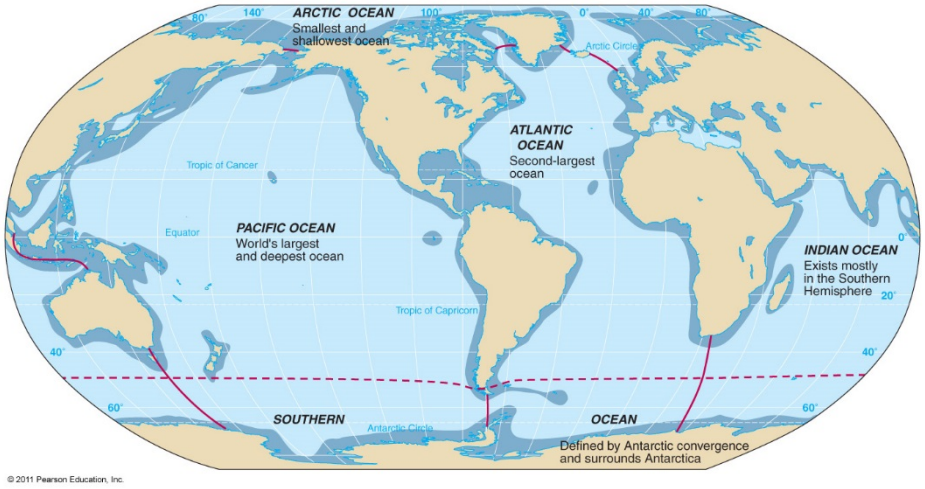
Geologic Time Scale



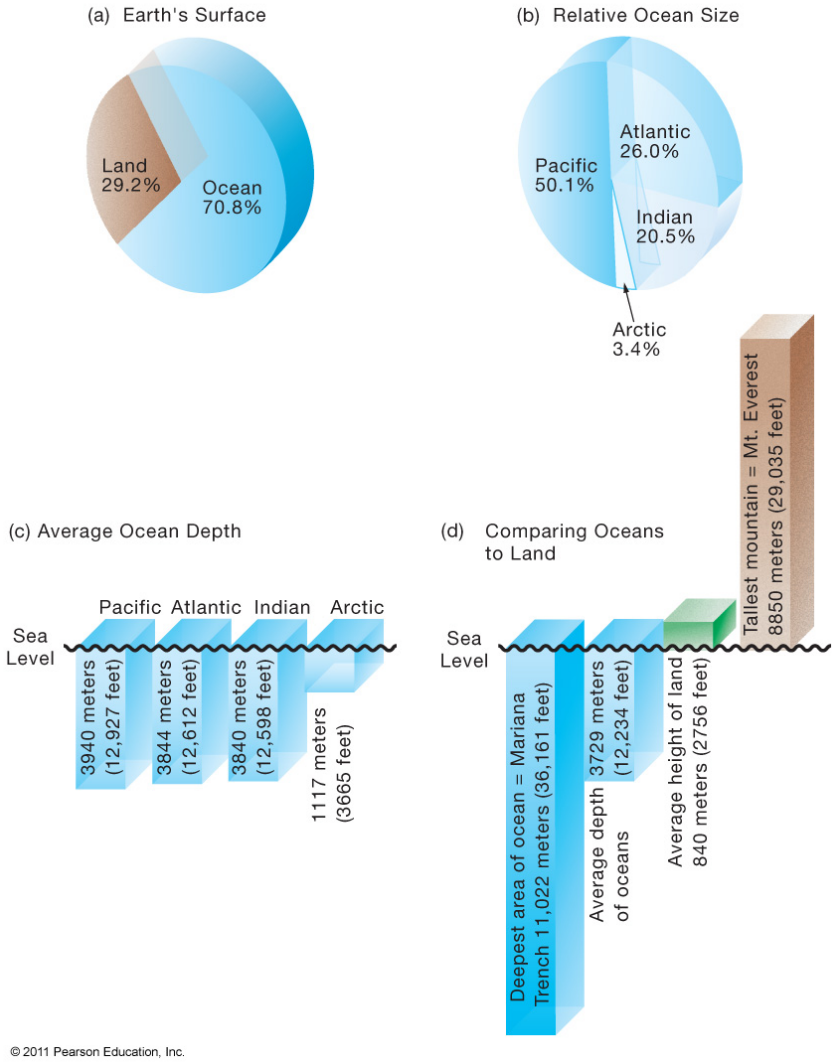
© 2011 Pearson Education, Inc.

Earth's Oceans

- Earth has one ocean.
- It is divided into four principle oceans, and one other.
  - Pacific Ocean
  - Atlantic Ocean
  - Indian Ocean
  - Arctic Ocean
  - Southern, or Antarctic Ocean



Ocean Size and Depth



Earth's Oceans

- Pacific Ocean
  - World's largest ocean
    - Accounts for more than half of Earth's ocean space
  - World's deepest ocean
  - Earth's largest geographic feature
  - Named in 1520 by Ferdinand Magellan

Earth's Oceans

- Atlantic Ocean
  - Half the size of the Pacific Ocean
  - Shallower than the Pacific Ocean
  - Separates the Old World from the New World
- Indian Ocean
  - Smaller than the Atlantic Ocean
  - Similar depth as the Atlantic Ocean
  - Primarily in the Southern Hemisphere

Earth's Oceans

- Arctic Ocean
  - Seven percent the size of the Pacific Ocean
  - Shallowest world ocean
  - Permanent layer of sea ice a few meters thick
- Southern Ocean or Antarctic Ocean
  - Circumnavigates Antarctica
  - Is really the parts of the Pacific, Atlantic, and Indian Oceans that lie south of 50° S latitude

The Seven Seas

- Smaller and shallower than oceans
- Salt water
- Usually enclosed by land
  - Sargasso Sea defined by surrounding ocean currents
- Directly connected to the ocean

The Seven Seas

- Before the 15th Century, Europeans considered the seven seas to be the following:
  1. Red Sea
  2. Mediterranean Sea
  3. Persian Gulf
  4. Black Sea
  5. Adriatic Sea
  6. Caspian Sea
  7. Indian Ocean

Comparing Oceans to Continents

- Average ocean depth is 3729 meters (12,234 feet)
- Average continental elevation is 840 meters (2756 feet)

- Deepest ocean trench is the Mariana Trench at 11,022 meters (36,161 feet)
- Highest continental mountain is Mt. Everest at 8850 meters (29,935 feet)