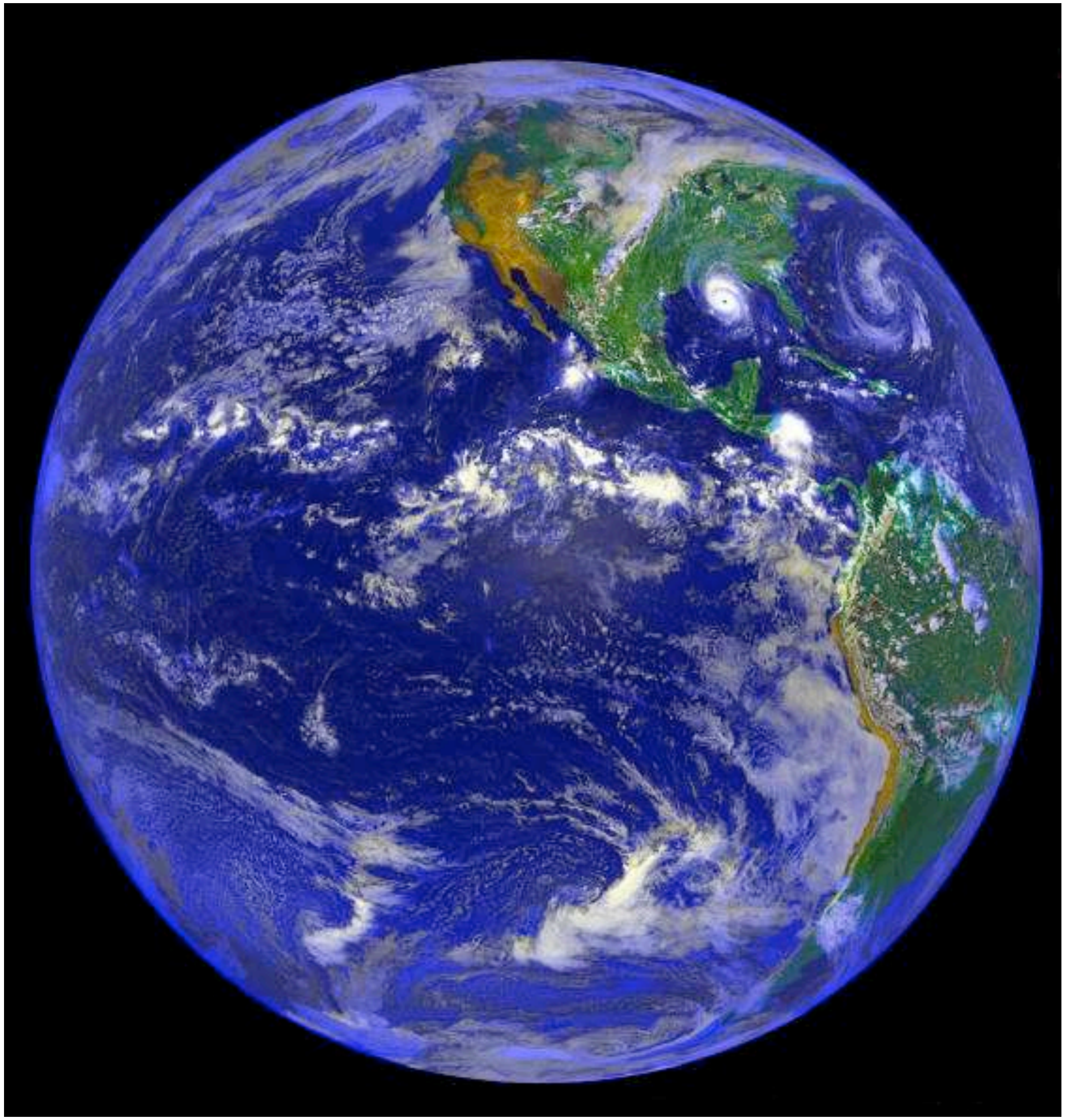
OCEANOGRAPHY

1. Introduction to Planet "Earth"

notes from the textbook, integrated with original contributions

Alessandro Grippo, Ph.D.



Are there other Oceans in the Solar System?

- Earth is the **only** planet where water is abundant, and it is in the liquid form

- Jupiter’s moon
  - Europa has an icy surface and cracked structures
  - Ganimede, Callisto might have ice under their crust

- Saturn’s moons
  - Enceladus has geysers of water vapor and ice
    - hydrothermal activity similar to that of Earth’s oceans
  - Titan has oceans of liquid hydrocarbons at its surface

Earth's Oceans

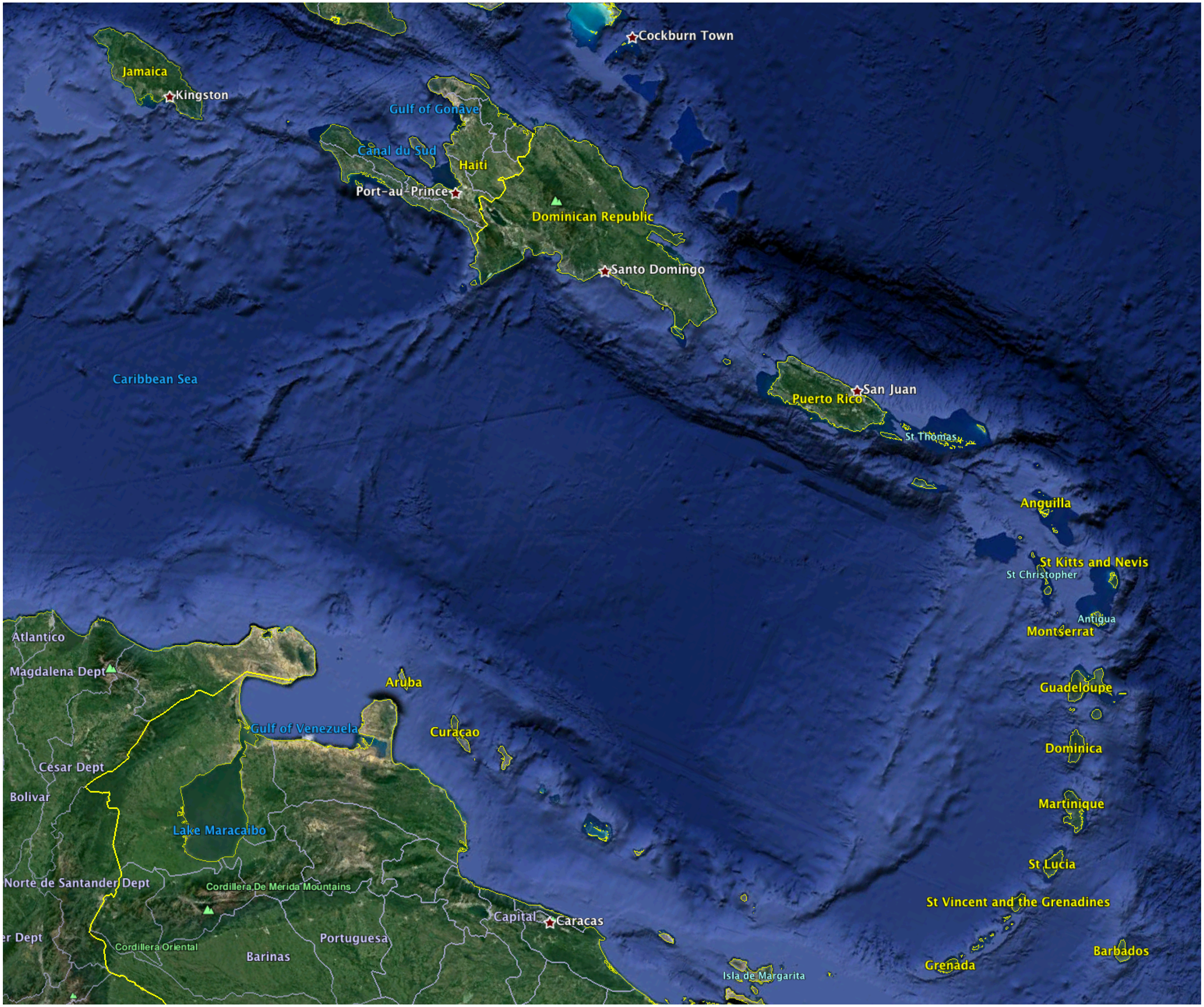
– essential for life today
– co-responsible for life development
– contain the greatest number of living organisms
– water is a major component of nearly every life-form

– influence climate and weather

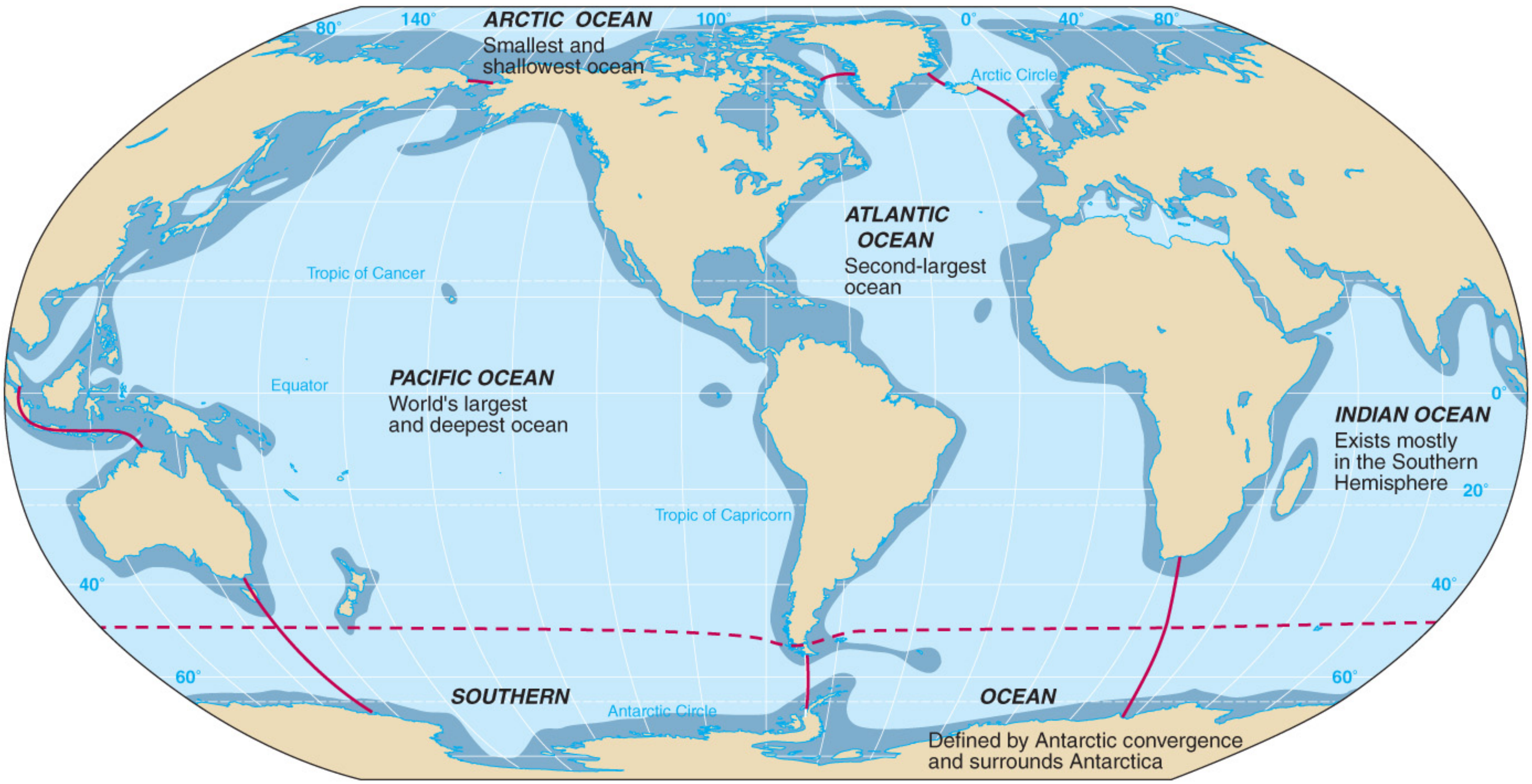
– source of food, minerals, energy

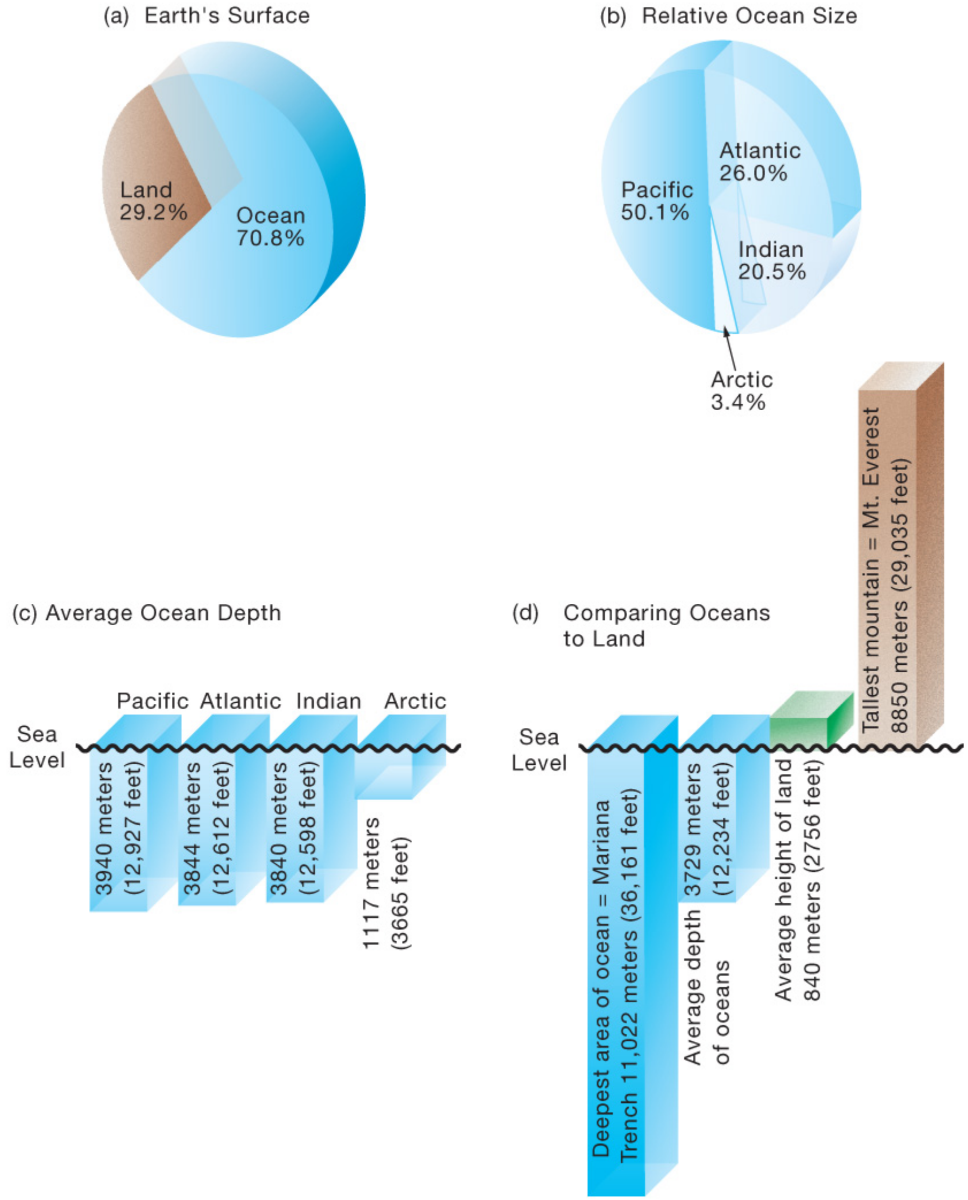
Earth’s Oceans and us

- oceans define geographical barriers
- oceans define political boundaries
- most people live in coastal areas
  - milder climate
  - cheaper transportation
  - pollution


Cockburn Town
Jamaica
Kingston
Gulf of Gonave
Canal du Sud
Haiti
Port-au-Prince
Dominican Republic
Santo Domingo
Caribbean Sea
San Juan
Puerto Rico
St Thomas
Anguilla
St Kitts and Nevis
St Christopher
Antigua
Montserrat
Guadeloupe
Dominica
Martinique
St Lucia
St Vincent and the Grenadines
Grenada
Barbados
Atlantico
Magdalena Dept
Aruba
Curaçao
Gulf of Venezuela
Cesar Dept
Bolivar
Lake Maracaibo
Norte de Santander Dept
Cordillera De Merida Mountains
Capital
Caracas
Cordillera Oriental
Portuguesa
Barinas
Isla de Margarita

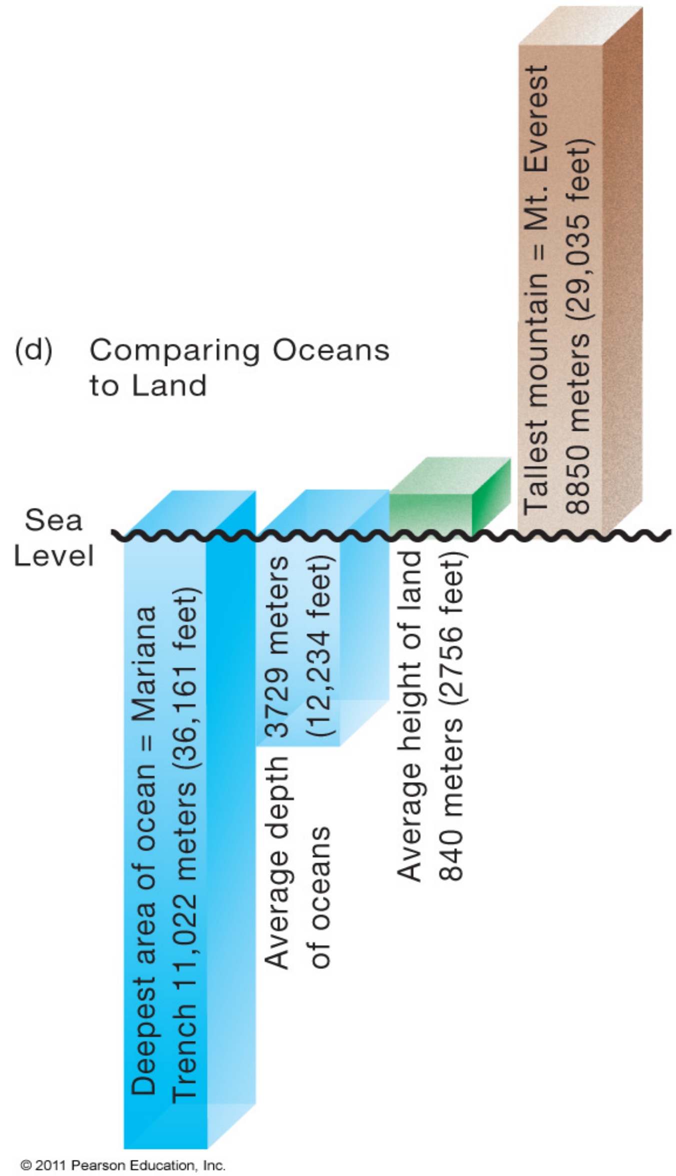
Earth’s Oceans




(a) Earth's Surface
Land
29.2%
Ocean
70.8%
(b) Relative Ocean Size
Pacific
50.1%
Atlantic
26.0%
Indian
20.5%
Arctic
3.4%
(c) Average Ocean Depth
Pacific
Atlantic
Indian
Arctic
Sea Level
3940 meters (12,927 feet)
3844 meters (12,612 feet)
3840 meters (12,598 feet)
1117 meters (3665 feet)
(d) Comparing Oceans to Land
Sea Level
Deepest area of ocean = Mariana Trench 11,022 meters (36,161 feet)
Average depth of oceans 3729 meters (12,234 feet)
Average height of land 840 meters (2756 feet)
Tallest mountain = Mt. Everest 8850 meters (29,035 feet)

- 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)



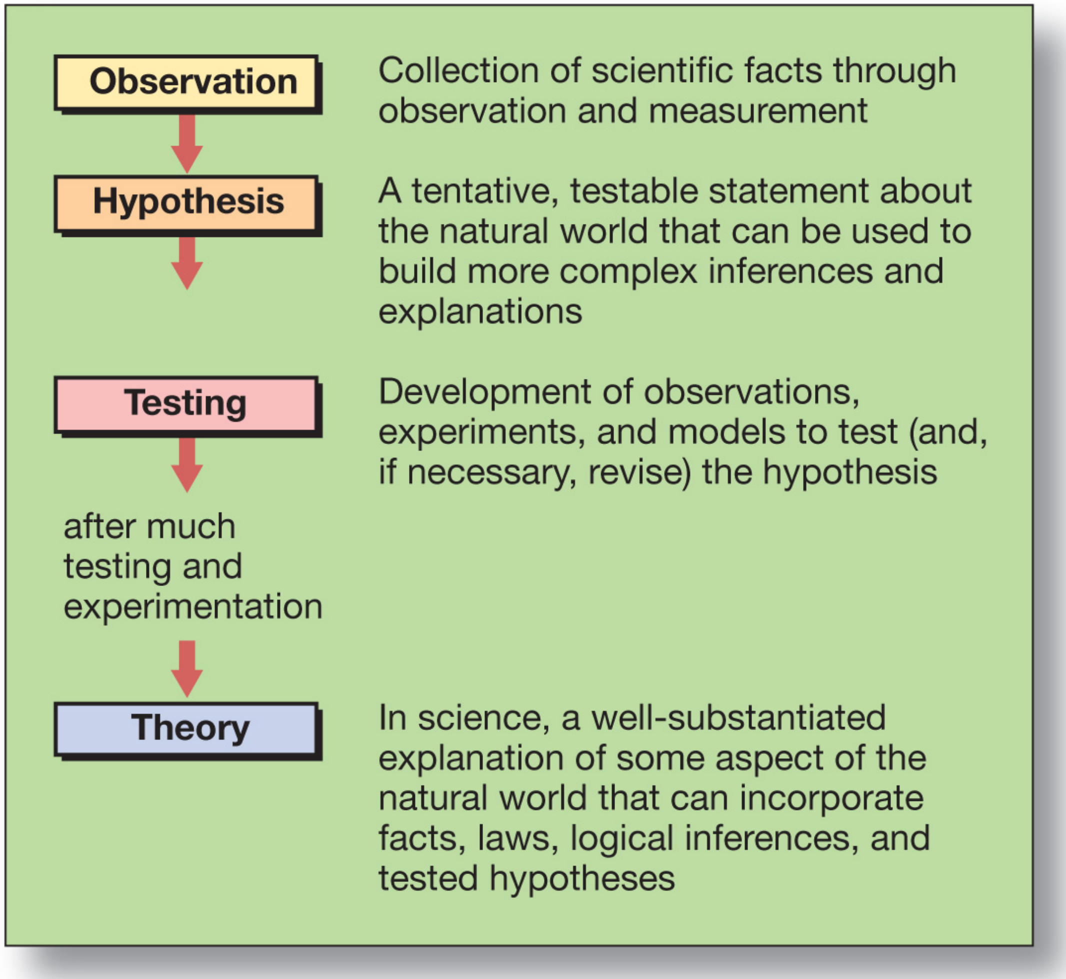
Oceanography

- Scientific study of all aspects of the marine environment

- Four main disciplines:
  - Geological Oceanography
  - Chemical Oceanography
  - Physical Oceanography
  - Biological Oceanography

Nature of Scientific Inquiry

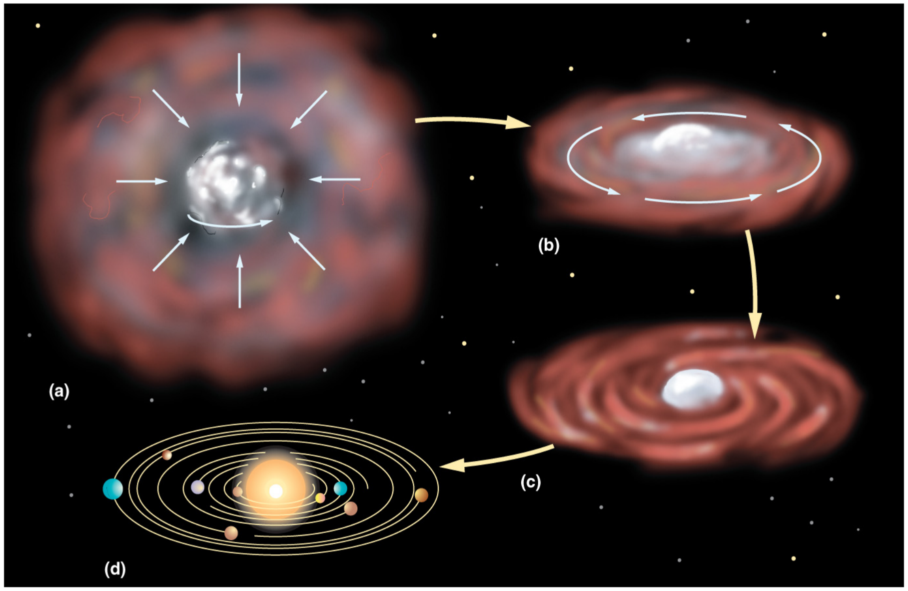
- Natural phenomena governed by physical processes
- Physical processes similar today as in the past
- Scientists discover these processes and make predictions
- Called the scientific method



Formation of Earth and the Solar System

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

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



Protoearth

- Larger than Earth today
- Homogeneous composition
- Bombarded by meteorites
  - Moon formed from collision with large asteroid
- Radioactive heat
  - Spontaneous disintegration of atoms
  - Fusion reactions
- Heat from contraction (protoplanet shrinks due to gravity)
- Protoearth partially melts
- Density stratification (layered Earth)

EARTH'S SYSTEM TODAY

- **A rocky physical body**
  - Core, Mantle, Oceanic Crust, Continental Crust
- **The Water**
  - Hydrosphere
    - Salt waters: Oceans
    - Fresh waters: Glaciers, Groundwater, Rivers, Lakes
    - Water vapor in the atmosphere
- **The Air**
  - Atmosphere
    - 79% N_2, 21% O_2, traces of CH_4, CO_2, NO_2, SO_2, H_2O and other gases
- **Living organisms**
  - Prokaryotes (Archaea, Bacteria)
  - Eukaryotes (Protists, Fungi, Plants, Animals)

Where do the components come from?

- Solid ROCKS formed when Earth cooled
- Liquids and gases were originally released during volcanic eruptions (WATER and ATMOSPHERIC GASES)
  - Water and air were retained thanks to gravitational force
- LIFE started as soon as Earth's surface was solid

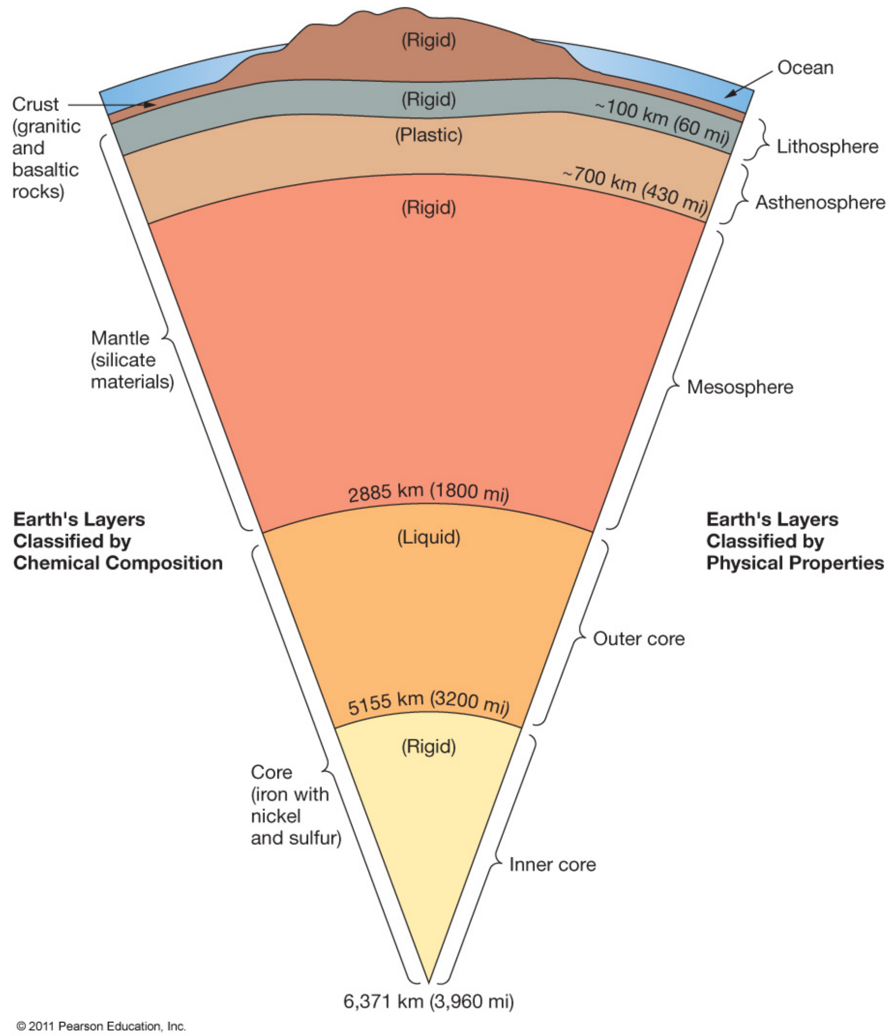
Density Stratification

- 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



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
  - Cool, rigid shell
  - Includes crust and upper mantle
  - About 100 km (60 miles) thick
- Asthenosphere
  - Relatively hot, plastic
  - Flows with high viscosity
  - Base of lithosphere to about 700 km (430 miles) deep
- Mesosphere
- Outer core
- Inner core

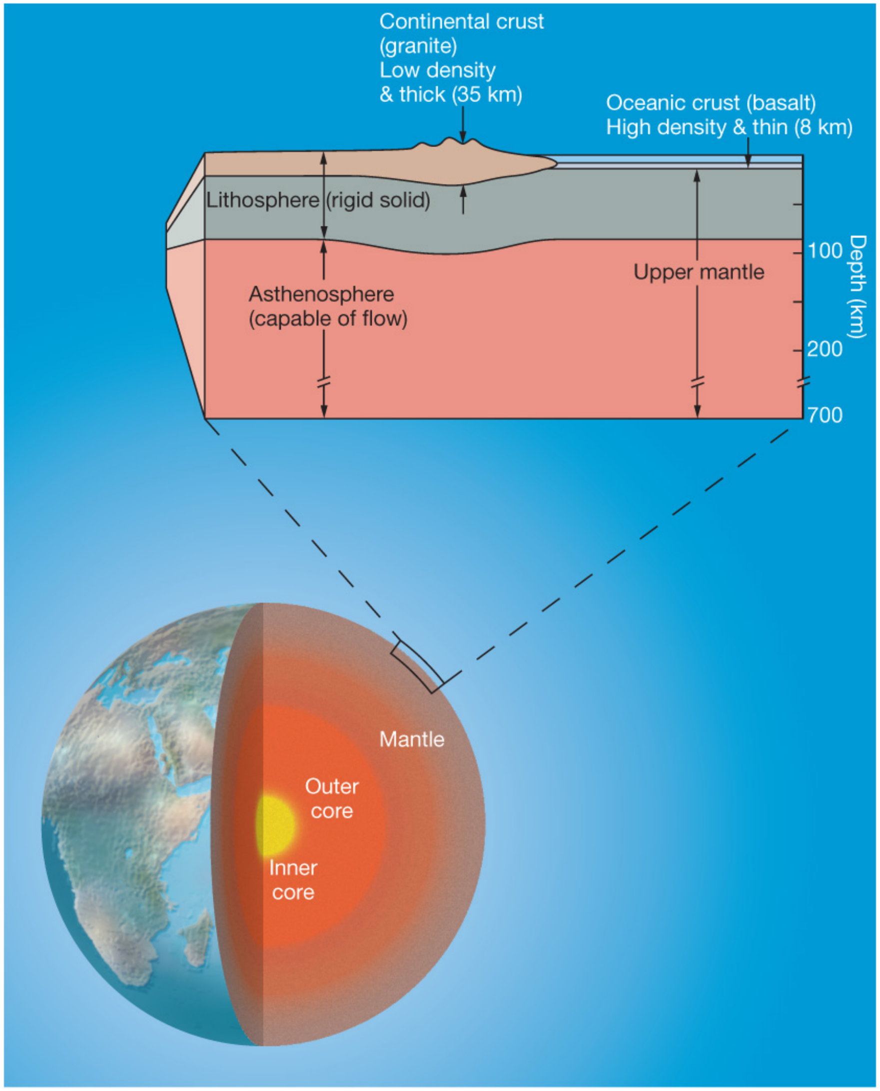
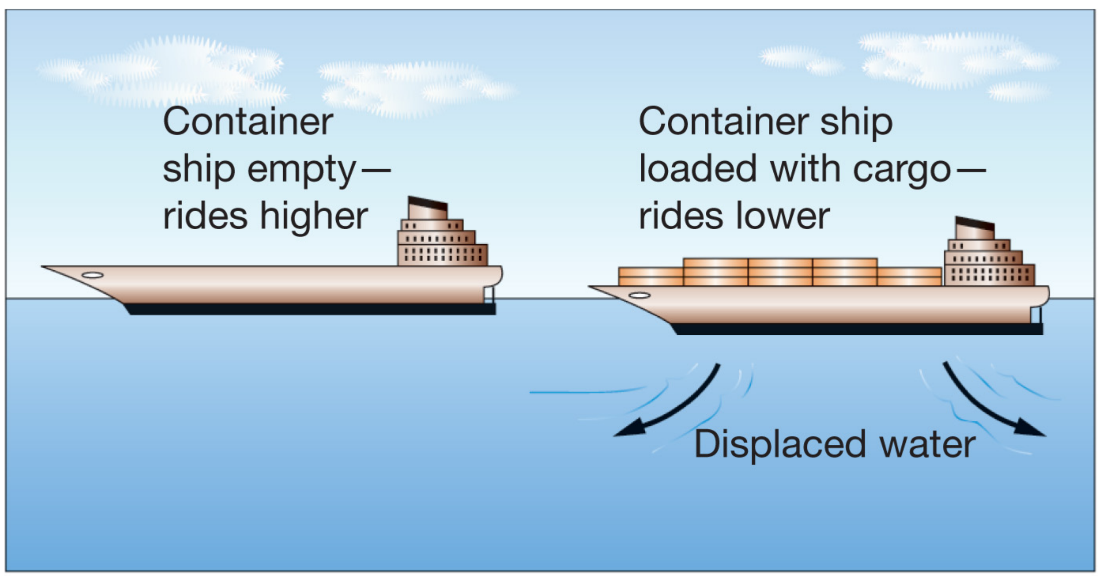


TABLE 1.1 COMPARING OCEANIC AND CONTINENTAL CRUST

	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)

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



WATER

- In Oceans
  - salt water; salinity is variable but the types and ratios of salt are identical all over the world in open oceans; mostly Na^+ and Cl^- ions

The Pacific Ocean: Howe Sound, by Vancouver, B.C. Canada

WATER

- In Rivers
  - fresh water; composition may vary, depending on source

The Virgin River in Zion National Park
Springdale, Utah

WATER

- In Lakes
  - fresh water or salt water ; if salty, type of salt may vary

An ephemeral, saline lake: Badwaters Death Valley National Park, California

WATER

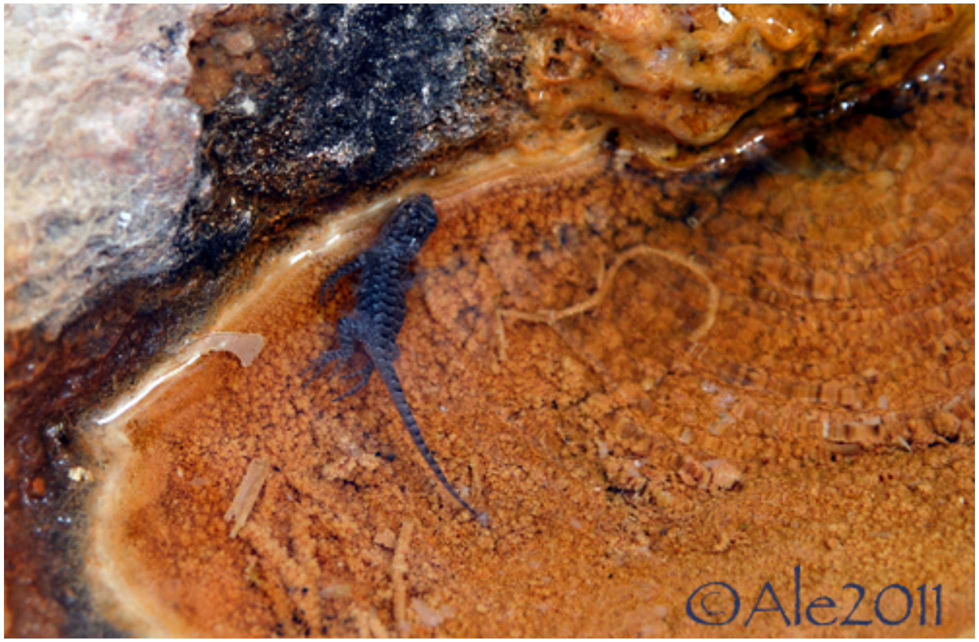
Convict Lake, Sierra Nevada, California

WATER

Mono Lake, Lee Vining, California

WATER

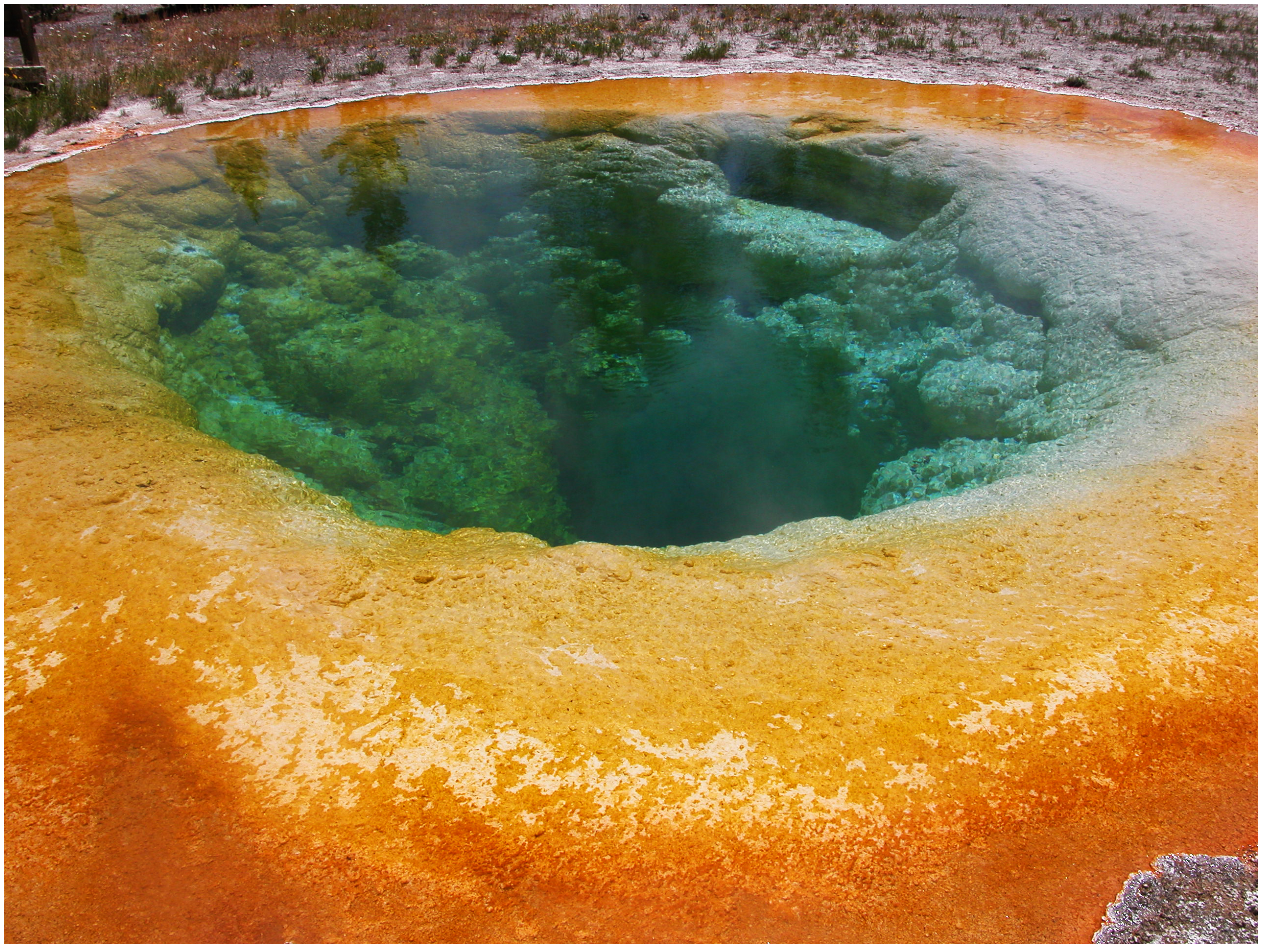
- As Groundwater
  - fresh water; can be salty close to ocean or at depth
  - temperature may vary: geothermal waters



Hot groundwater upwells at this location, killing animals who fall into pools, and causing deposition of calcium carbonate (orange crystals)

Hot Springs by Bridgewater, California

WATER



Hot water pools in **Yellowstone National Park, WY**
the colors are the result of different colonies of bacteria that thrive in progressively lower water temperatures

WATER

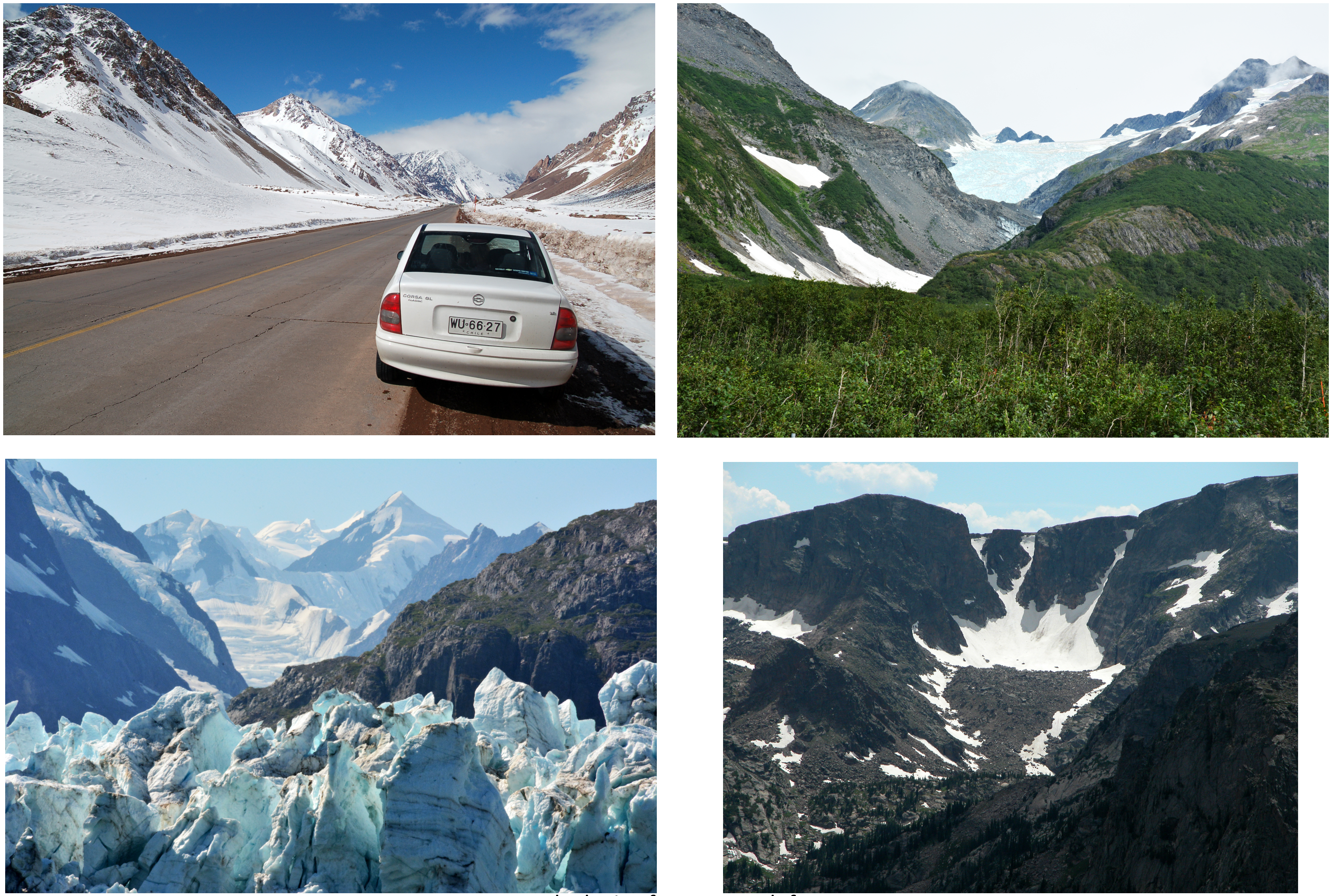
A geyser in Yellowstone National Park, WY

WATER

- As Ice
  - Ice on continents
  - Ice pack (sea ice), can contain up to 0.8% salt
  - Alpine ice

Glacier Bay, Gustavus, Alaska

WATER



clockwise from upper left:
the Andes at the Chile/Argentina border; the Alaska Range in Seward, AK;
a glacial cirque in the Rocky Mountains, CO; a glacier in the Coast Mountains, AK

WATER

- As Water Vapor
  - Atmospheric moisture, usually “distilled” water
  - Percentage of water in atmosphere can vary

Clouds over the island of **Maui, Hawaii**

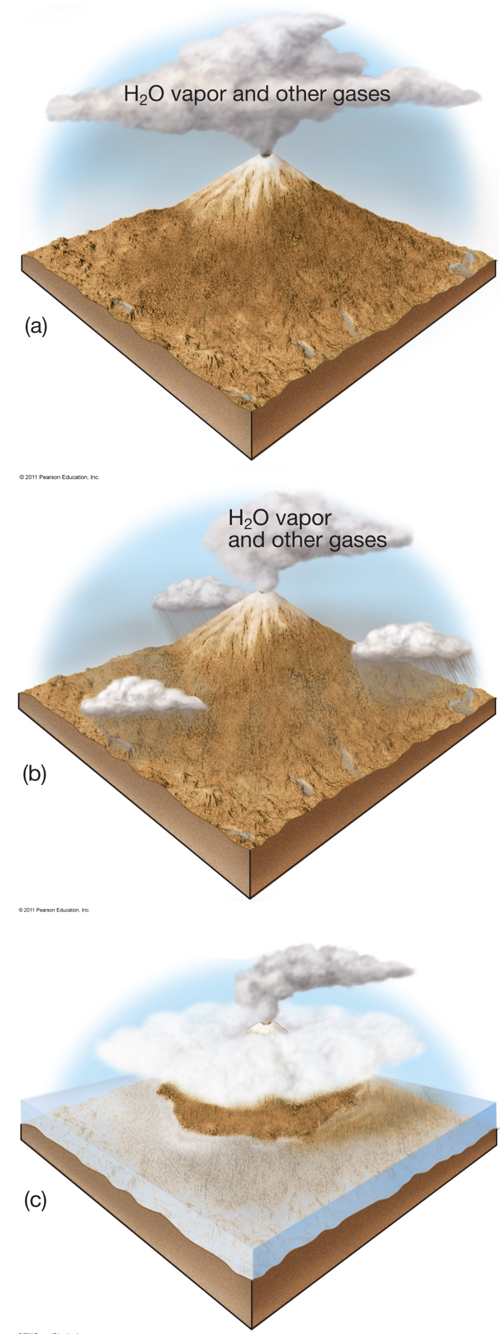
WATER

- In Rocks
  - directly as water (e.g. Gypsum, $CaSO_4$*$2H_20$)
  - trapped in clay minerals
  - as OH^- ions that can promptly react with H^+ ions

- In Living Organisms
  - Plants (evaporation and transpiration processes)
  - Animals

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.



Origin of Earth’s Atmopshere

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

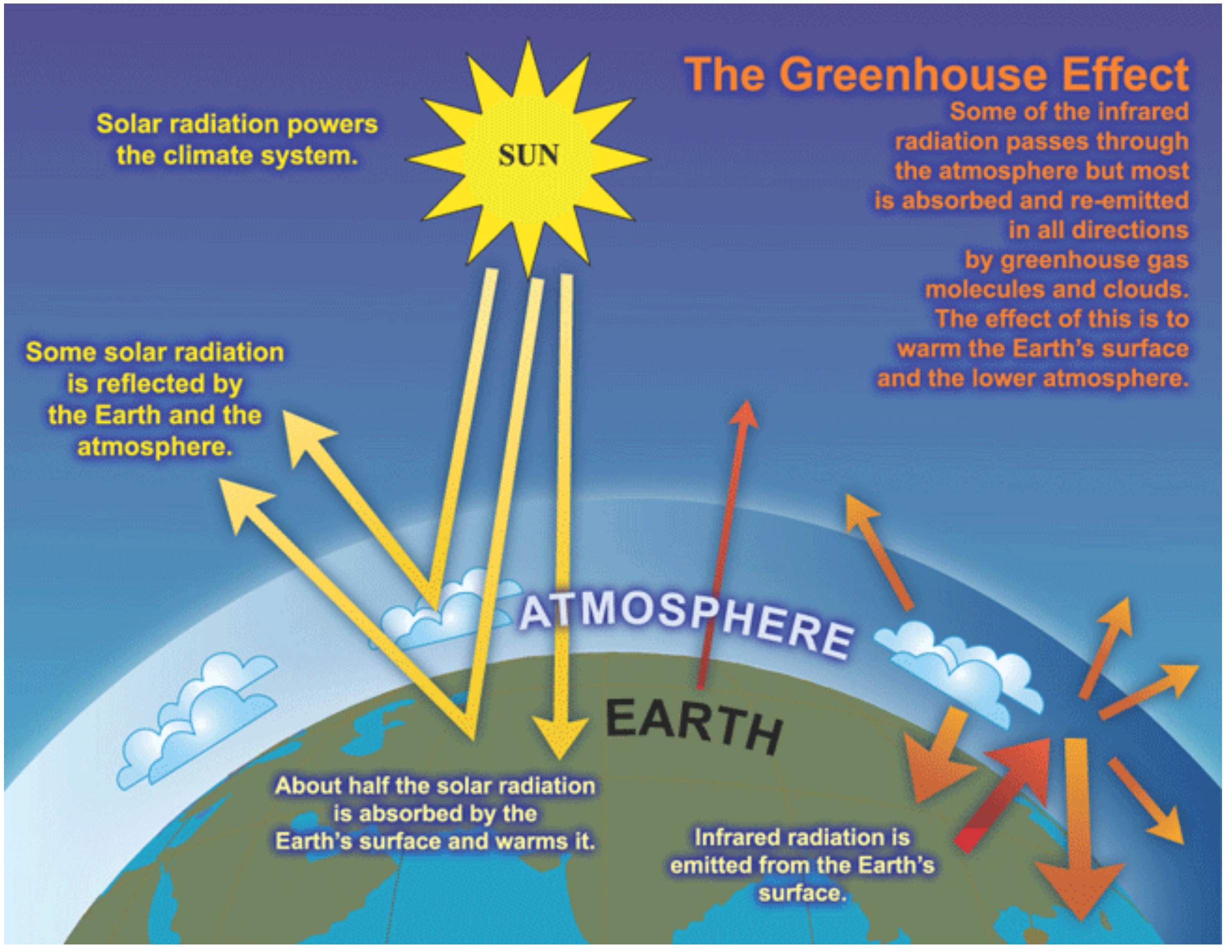
AIR

- Nitrogen: 78%
- Oxygen: 21%
- other gases: ~ 1%
  - (CO_2, NO_2, CO, NO, CH_4, H_2O, and others)

in orange: greenhouse gases

AIR

- Greenhouse gases:
  - Solar radiation can penetrate greenhouse gases
  - Radiation is reflected back by Earth, but at a different frequency
  - Greenhouse gases trap the radiation emitted by Earth
  - More greenhouse gases in the atmosphere imply warmer temperatures



from www.co2now.org

Life's Possible Ocean Origins

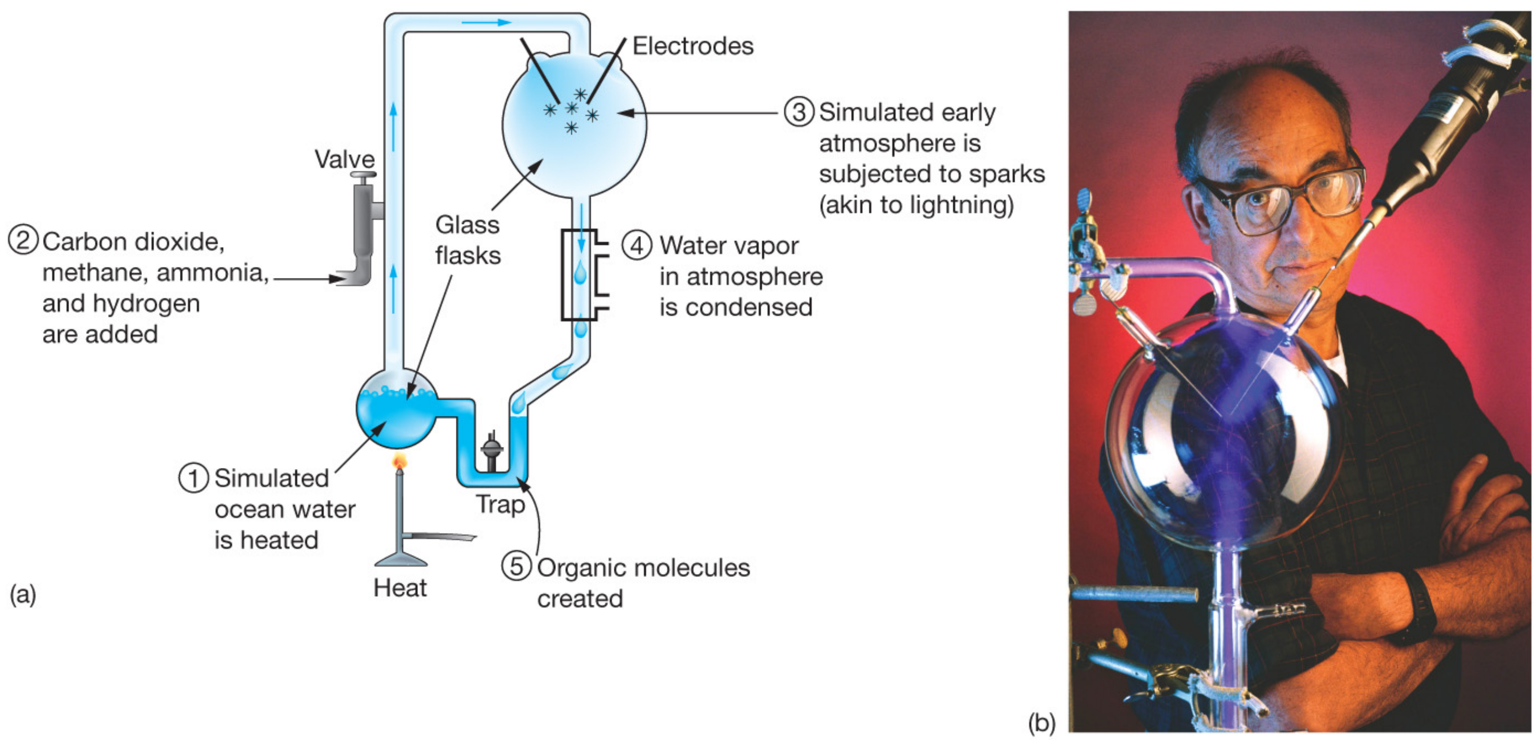
- Earth's earliest known life forms are 3.5-billion-year-old bacteria fossilized in ocean rocks.

- Started as:
  - chemosynthetic
  - prokaryotic
  - mitotic
  - single celled

- Evolved in time into:
  - photosynthetic
  - eukaryotic
  - meiotic (sexual reproduction)
  - colonial
  - from colonial to multicellular
  - from simple (e.g. sponges) to specialized (e.g. plants and animals)

Stanley Miller's Experiment

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



- 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

Phptosynthesis and Respiration

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

- Photosynthesis

solar energy

$6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$

carbon dioxide + water → sugar + oxygen

- Respiration

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_20$

sugar + oxygen → carbon dioxide + water

release of (solar) energy stored in sugar

- All organisms modify the environment
  - Photosynthesis
    - added oxygen to atmosphere
    - oxygen provides more energy as a fuel
    - life development sped up
  - Carbonate reefs
    - today they are limited, more developed in the past
  - Human activity

Oxygen

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

- Destruction vs. Preservation of Organic Matter
  - oxygen is needed to burn sugars
  - upon death, bodies are recycled by scavengers, decomposers, who all need oxygen
  - if there is no oxygen, organic matter (the sugars) do not decompose and are preserved, albeit modified
  - this preserved organic matter that escaped decomposition makes for hydrocarbons (oil and natural gas)

Great Oxidation Event

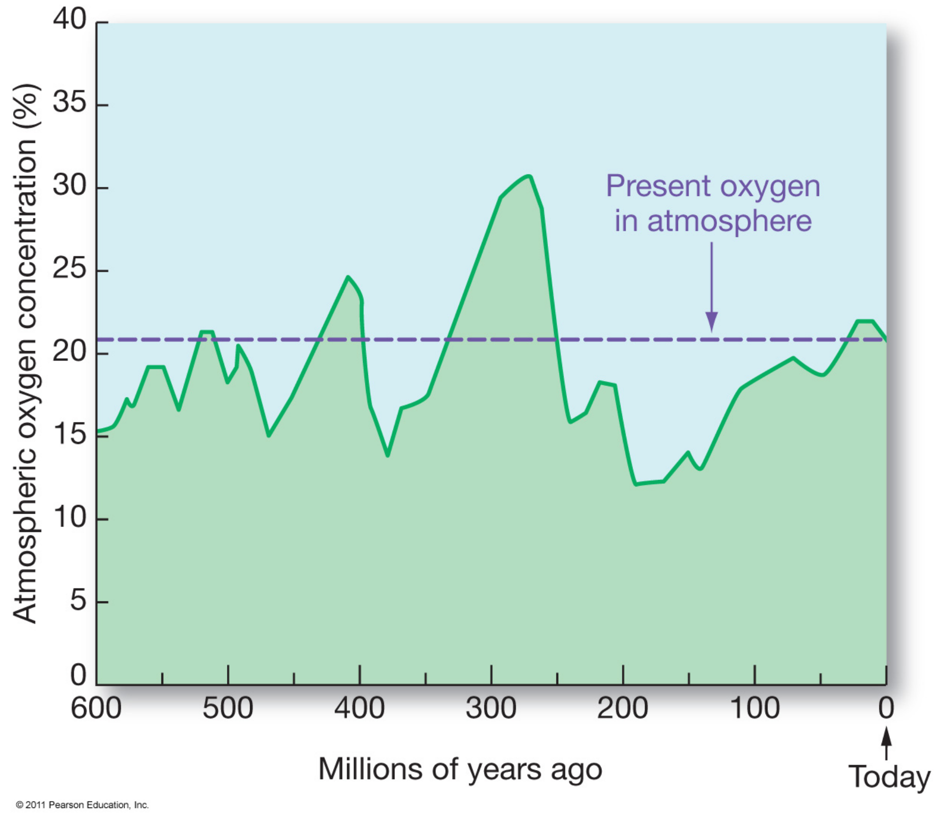
- 2.45 billion years ago
- Increased oxygen and ozone eliminated the anaerobe food supply.
- Light and oxygen kill anaerobes.
- Cyanobacteria adapted and thrived.

Evolution and Natural Selection

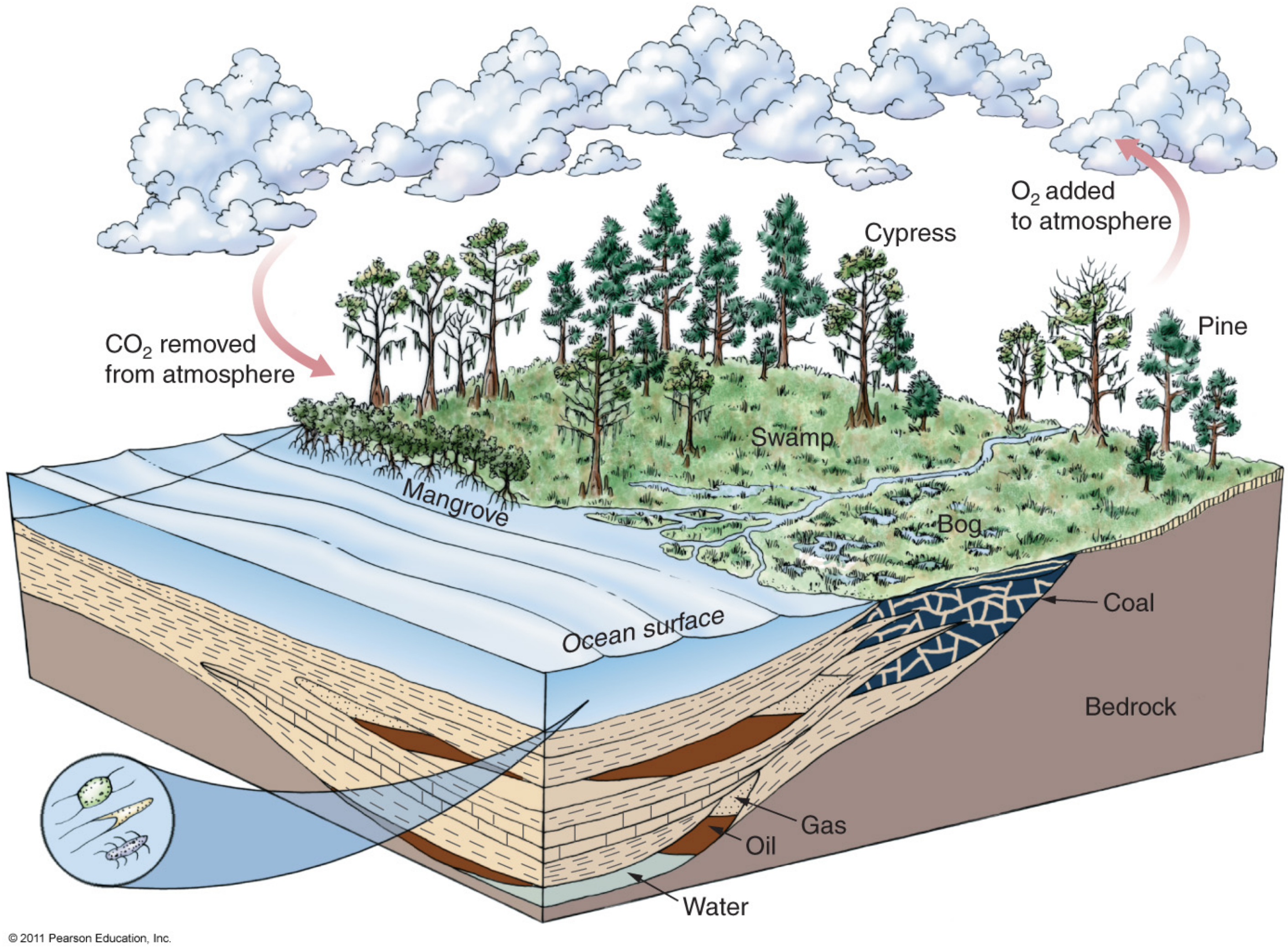
- Organisms adapt and change through time.
- Advantageous traits are naturally selected.
- Traits are passed to the next generation.
- Organisms adapt to environments.
- Organisms can modify environments.

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



Algae, Plants, and Earth's Environment



Age of Earth

Deep time

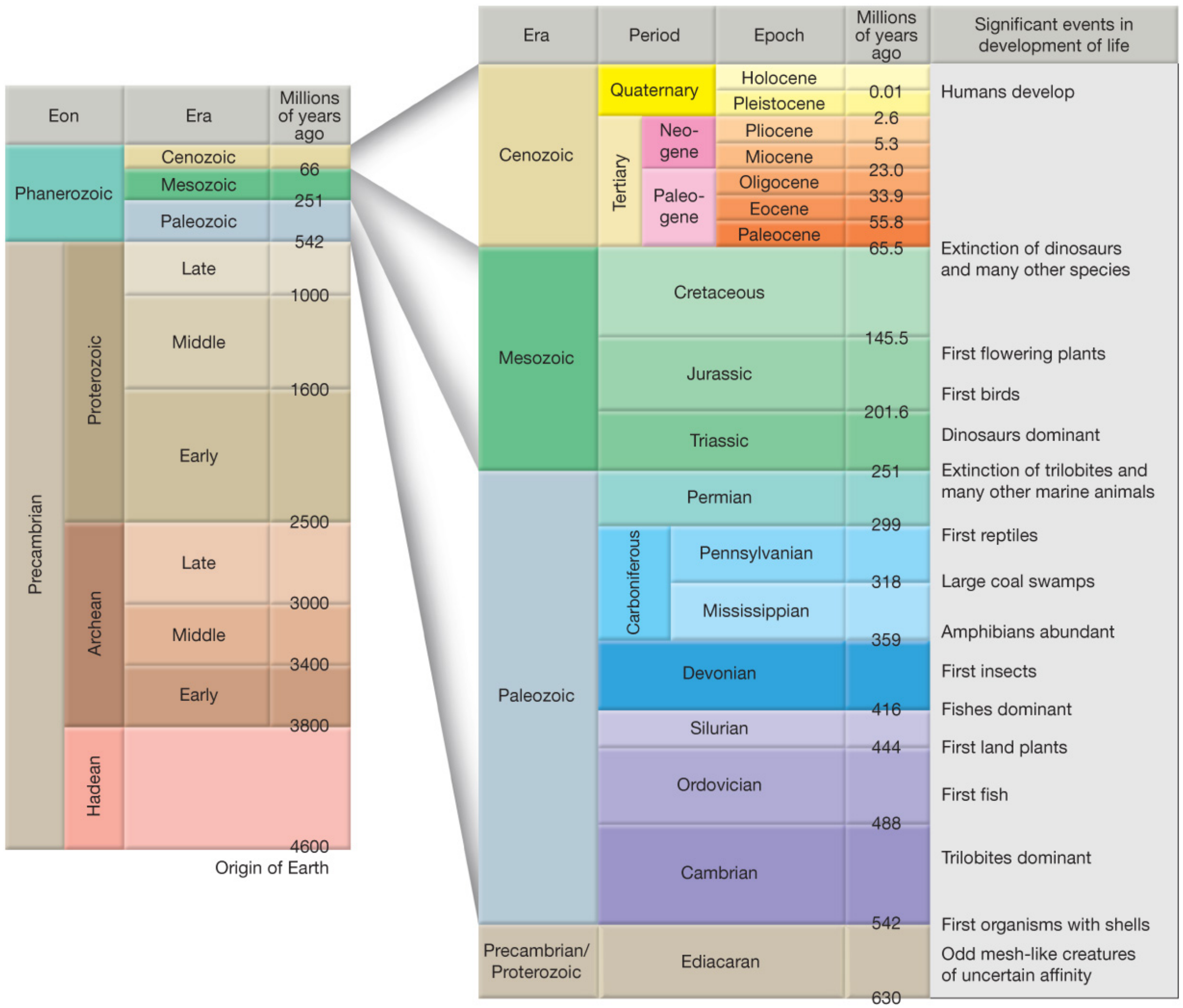
– Geology shows that Earth is 4.6 billion years old
– Humans have been around for an incredibly smaller amount of time

- Relative Time
- Numerical Time

DEEP TIME

- Relative Time approach
  - tells us the order of event, not their age
  - basic principles make it easy
  - can be done visually in the field

- Numerical Time approach
  - tells us the numerical age of rocks and/or events
  - can only be done in the lab
  - it only works on certain rocks
  - it is expensive and time-consuming


Eon
Era
Millions of years ago
Phanerozoic
Cenozoic
66
Mesozoic
251
Paleozoic
542
Precambrian
Proterozoic
Late
1000
Middle
1600
Early
2500
Archean
Late
3000
Middle
3400
Early
3800
Hadean
4600
Origin of Earth
Era
Period
Epoch
Millions of years ago
Significant events in development of life
Cenozoic
Quaternary
Holocene
Pleistocene
0.01
Humans develop
Tertiary
Neo- gene
Pliocene
2.6
Miocene
5.3
23.0
Paleo- gene
Oligocene
33.9
Eocene
55.8
Paleocene
65.5
Extinction of dinosaurs and many other species
Mesozoic
Cretaceous
145.5
First flowering plants
Jurassic
First birds
201.6
Triassic
Dinosaurs dominant
251
Extinction of trilobites and many other marine animals
Paleozoic
Permian
299
First reptiles
Carboniferous
Pennsylvanian
318
Large coal swamps
Mississippian
359
Amphibians abundant
Devonian
First insects
416
Fishes dominant
Silurian
444
First land plants
Ordovician
First fish
488
Cambrian
Trilobites dominant
542
First organisms with shells
Precambrian/ Proterozoic
Ediacaran
Odd mesh-like creatures of uncertain affinity
630