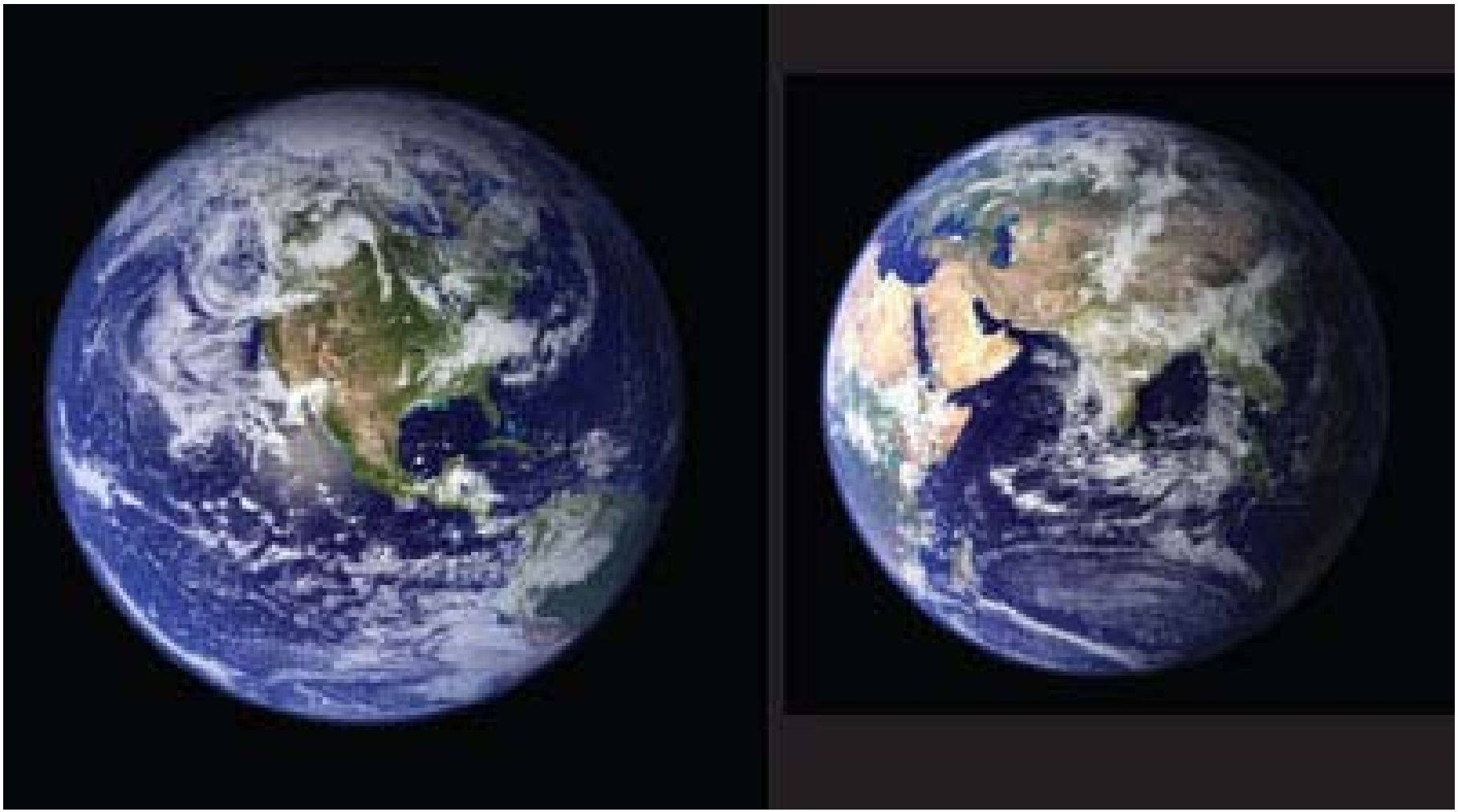
The Living Earth



Chapter Nine

Introduction To Modern Astronomy I: Solar System

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-15)

Chap. 16:
Chap. 28:

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II

Ch9: The Living Earth

Ch10: Our Barren Moon
Ch11: Earthlike Planets
Ch12: Jupiter and Saturn
Ch13: Satellites of Jupiter & Saturn
Ch14: Uranus, Neptune and Beyond
Ch15: Vagabonds of Solar System

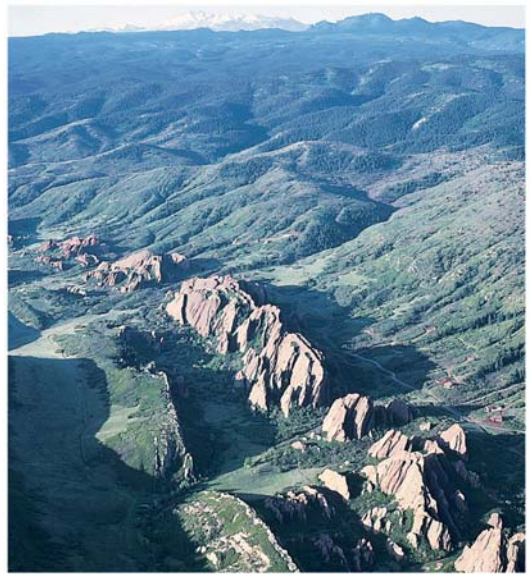
Energy Source of Earth

- Three energy sources power all the activities on Earth
    1. Radiation from the Sun
    2. Tidal forces from Moon
    3. Internal heat of Earth (left over from the creation)

•Atmosphere is powered by solar energy

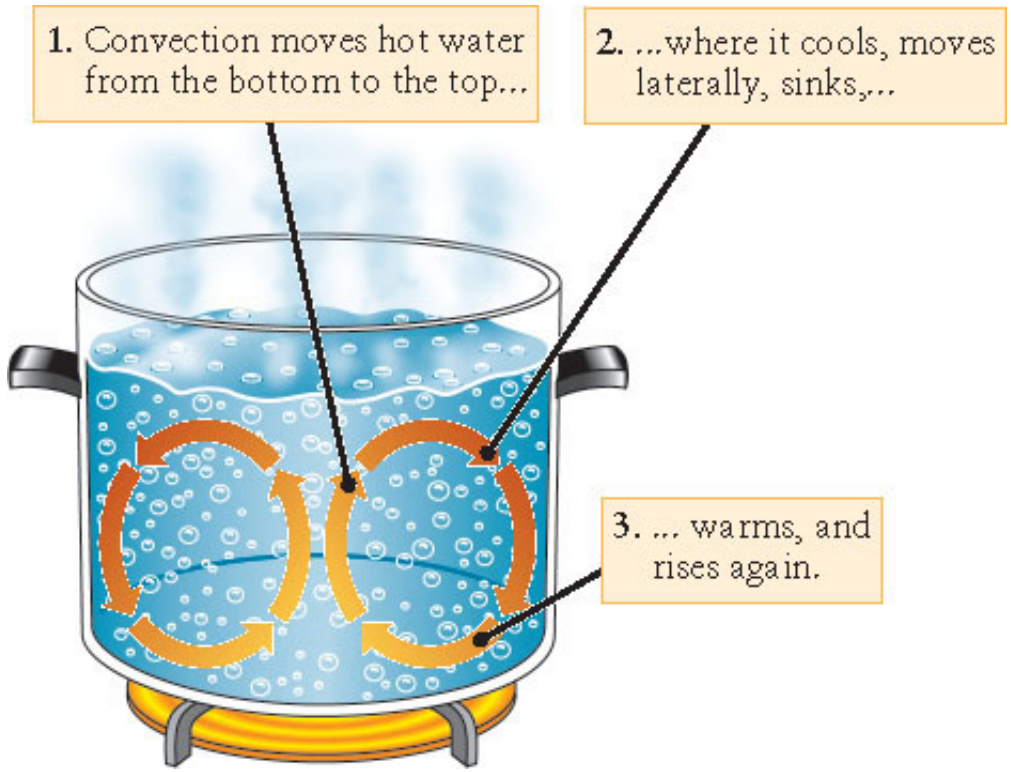
•Ocean is powered by tidal forces (and radiation)

•Land is powered by the internal heat



Atmosphere: Convection

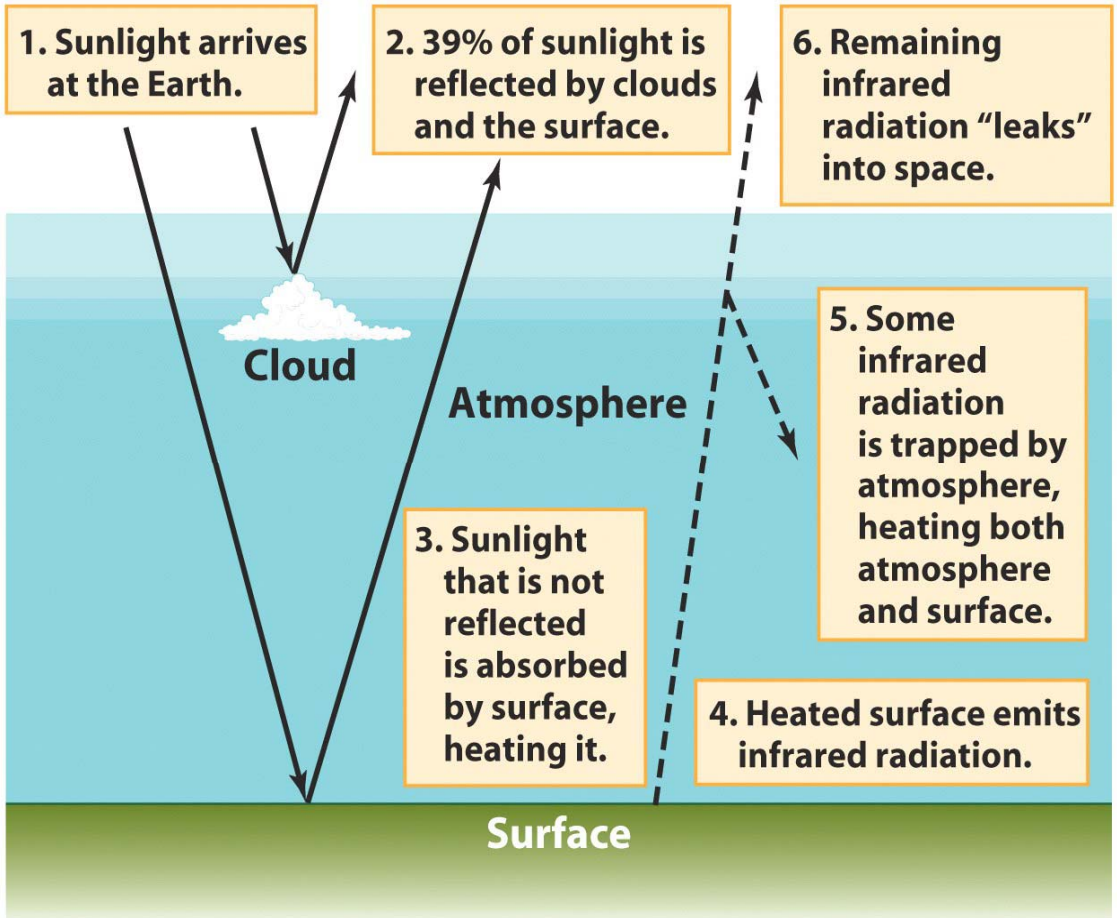
- **Convection**: up and down motion
- Radiation energy from the Sun causes **convection**
  - Atmosphere is transparent to sunlight
  - Sunlight warms the Earth's surface, which warms the air next to the surface
    - Hot air rises.
    - Rising air cools and becomes denser
    - It then sinks downward to be heated



Atmosphere: Greenhouse Effect

- **Greenhouse effect: greenhouse gases** in the atmosphere trap the infrared radiation emitted from the Earth's surface, and raise the temperature of the atmosphere

- **Greenhouse gases:**
  - **Water** (1%)
  - **CO_2** (0.035%)
- Main Composition
  - 78% Nitrogen
  - 21% Oxygen
  - Not Greenhouse gases



Atmosphere: Greenhouse Effect

- The greenhouse effect raises the Earth's surface temperature by 33°C, which is beneficial
  - The average surface temperature is 14°C
  - If no greenhouse effect, the calculated surface temperature would be about -19°C
    - Energy input: solar radiation

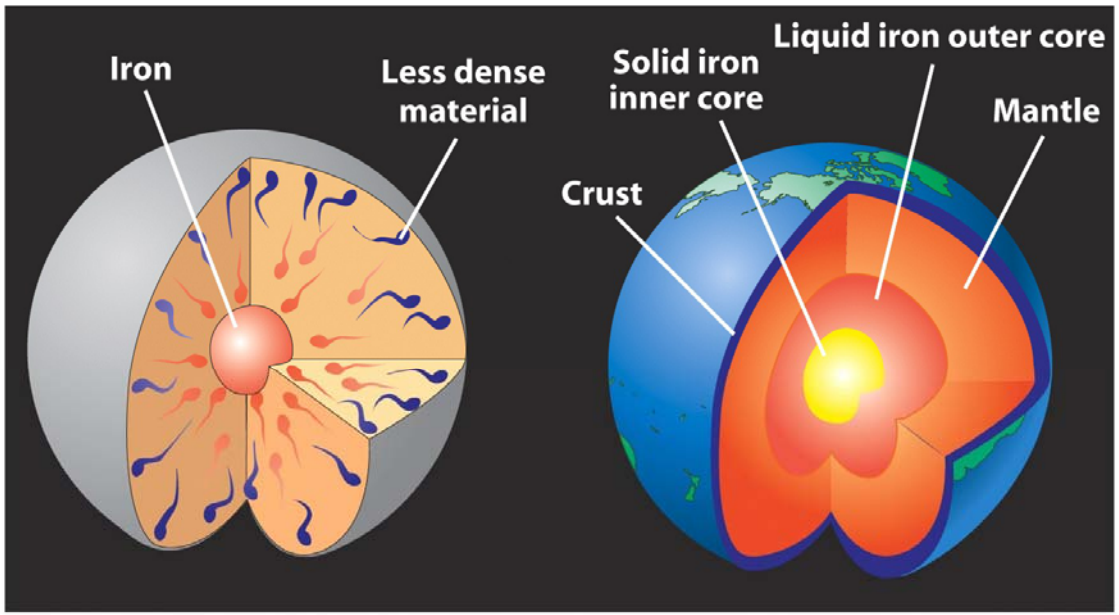
      minus reflection (albedo)
    - Energy output:

      Earth radiation → -19°C

      minus greenhouse effect → 14°C

Earth's interior structure

- Earth has layered structure due to **chemical differentiation**
  - When Earth was newly formed, it was molten throughout its volume due to the heat from impact
  - Dense materials such as iron sank toward the center
  - Low-density materials rose toward the surface



(a) During differentiation, iron sank to the center and less dense material floated upward

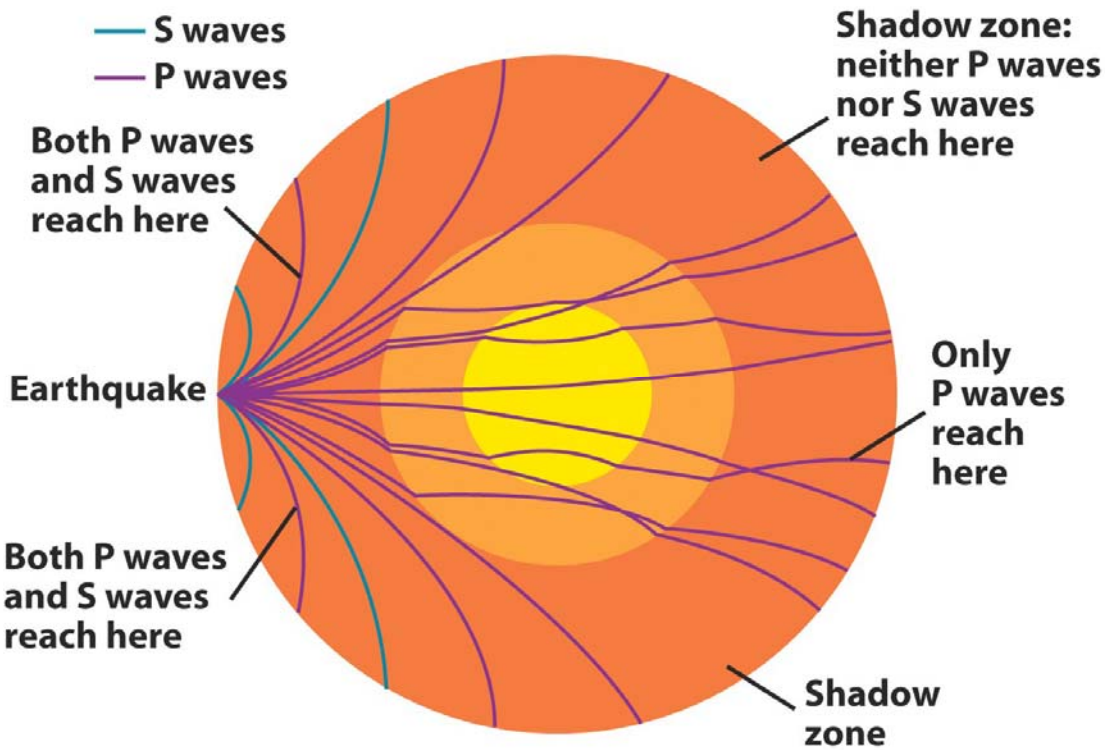
(b) As a result of differentiation, the Earth has the layered structure that we see today

Earth's Interior Structure

- Earth has largely three layers:
  - **Crust:**
    - 5 km to 35 km deep
    - solid,
    - Relatively light silicon-rich minerals
  - **Mantle:**
    - 2900 km deep
    - solid
    - heavy iron-rich minerals
  - **Core:**
    - made of pure iron
    - Outer core: liquid
    - Inner core: solid

Earth’s interior structure

- Earth’s internal structure is deduced by studying how the **seismic waves produced by Earthquakes** travel through the Earth’s interior
- **Seismic waves refract or change the path because of differences in the density of the material**



Earth's interior structure

- The state (solid or liquid) depends on the actual temperature relative to the **melting point**
- **Melting point** is determined by chemical composition and pressure
- **Asthenosphere**, which is at the top of the mantle, is at a state called "plastic"
  - that is able to flow slowly.
  - It causes the movement of the crust

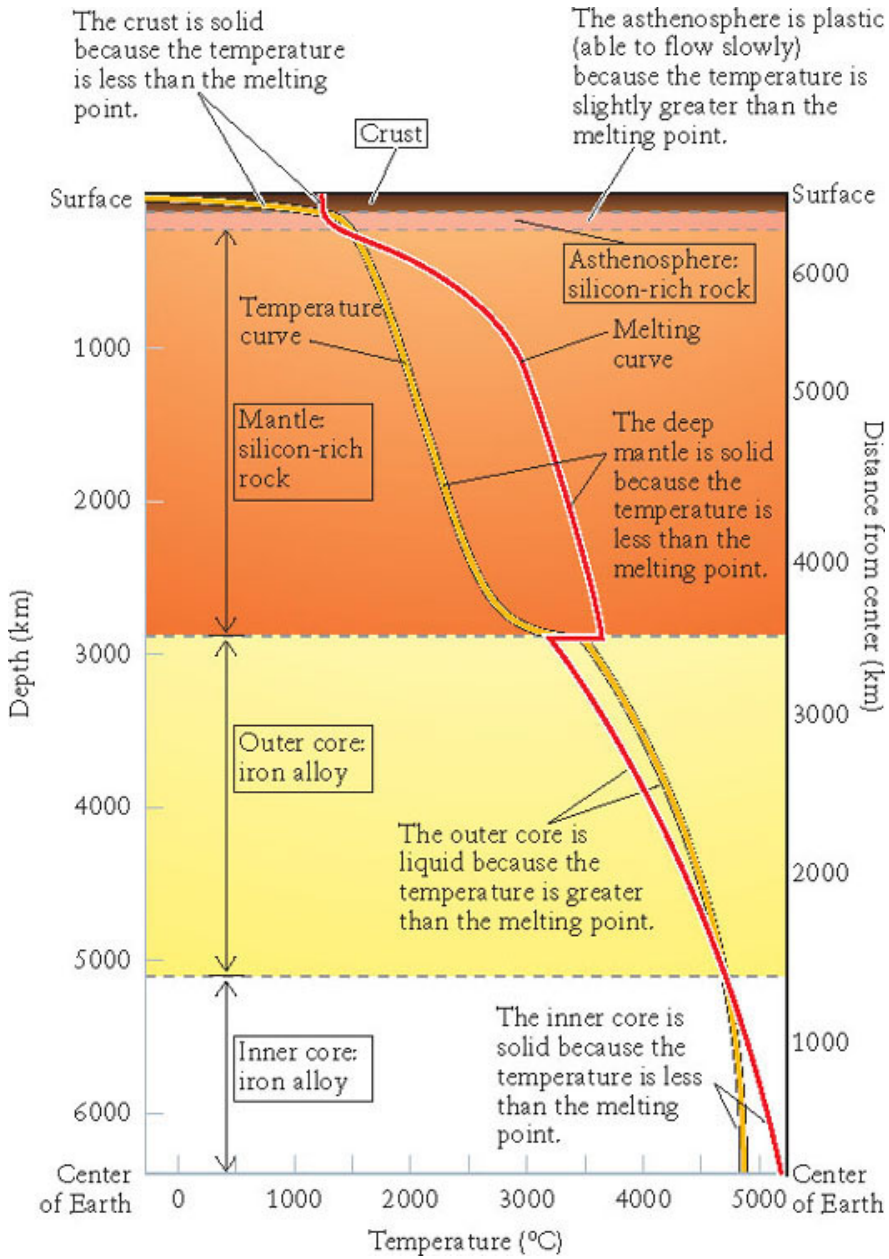


Plate Movement

- Alfred Wegener, inspired by the world map, suggested the idea of “continental drift” in 1915.
- All continents have originally been a single gigantic supercontinent, called **Pangaea** (meaning “all lands”)

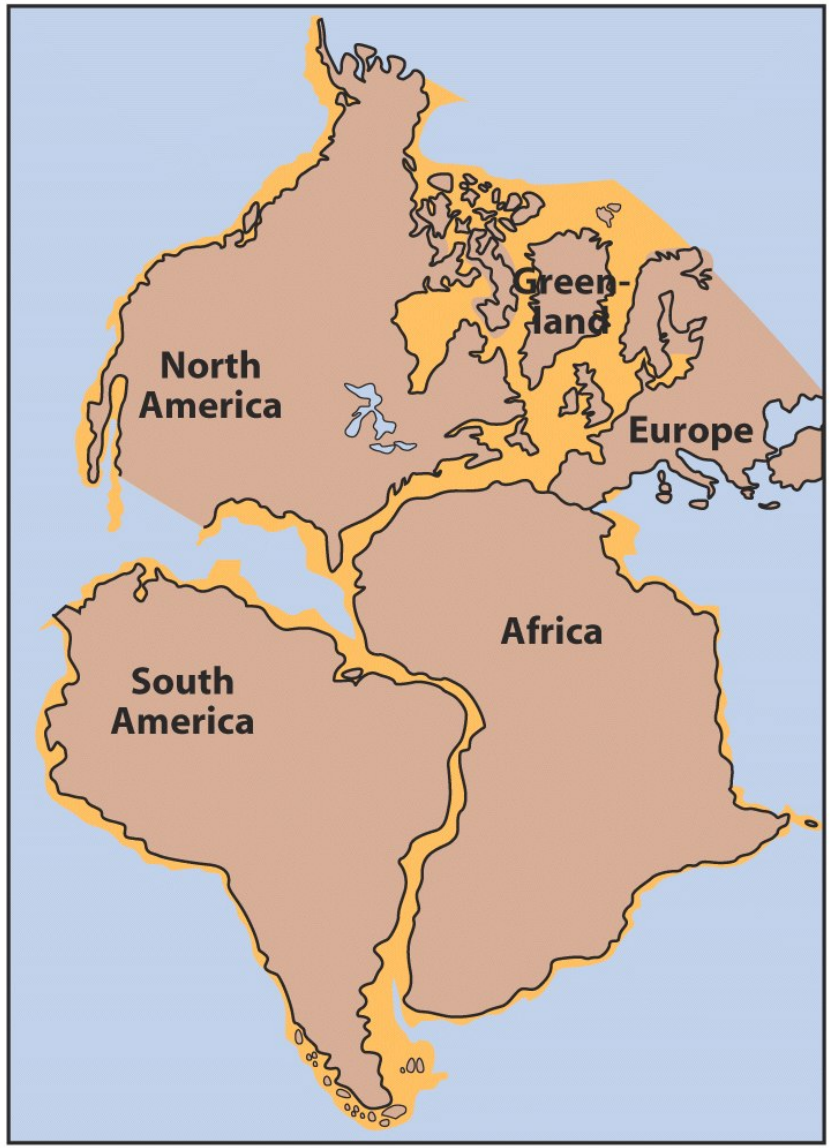
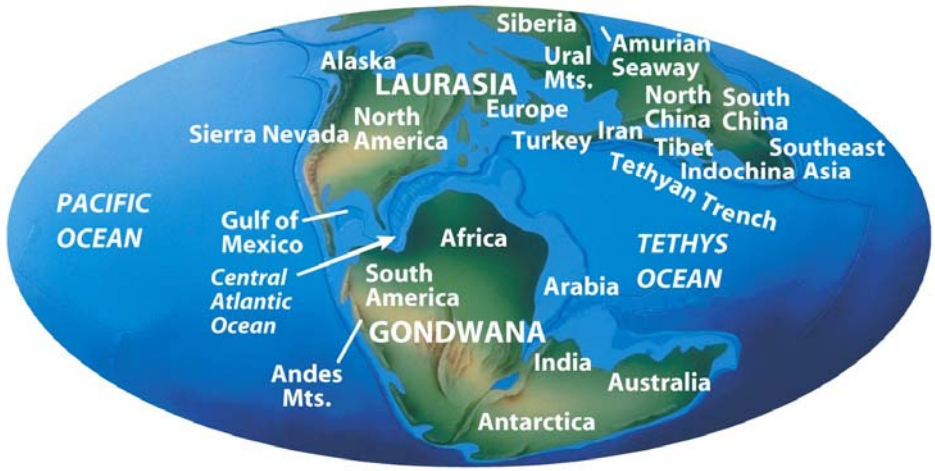


Plate Movement

(a) 237 million years ago: the supercontinent Pangaea

(b) 152 million years ago: the breakup of Pangaea



(c) The continents today

- drifting speed is several cm per year

  e.g., at 3 cm/year over 200 million years, the drifting distance is 6000 km

Plate Movement

- **Plate tectonics** (meaning “builder”) is caused by the **internal heat** of the Earth.
- Internal heat causes convection flows in asthenosphere
- Molten material from asthenosphere wells up at **oceanic rifts**, producing seafloor spreading, and is returned to the asthenosphere in **subduction** zones

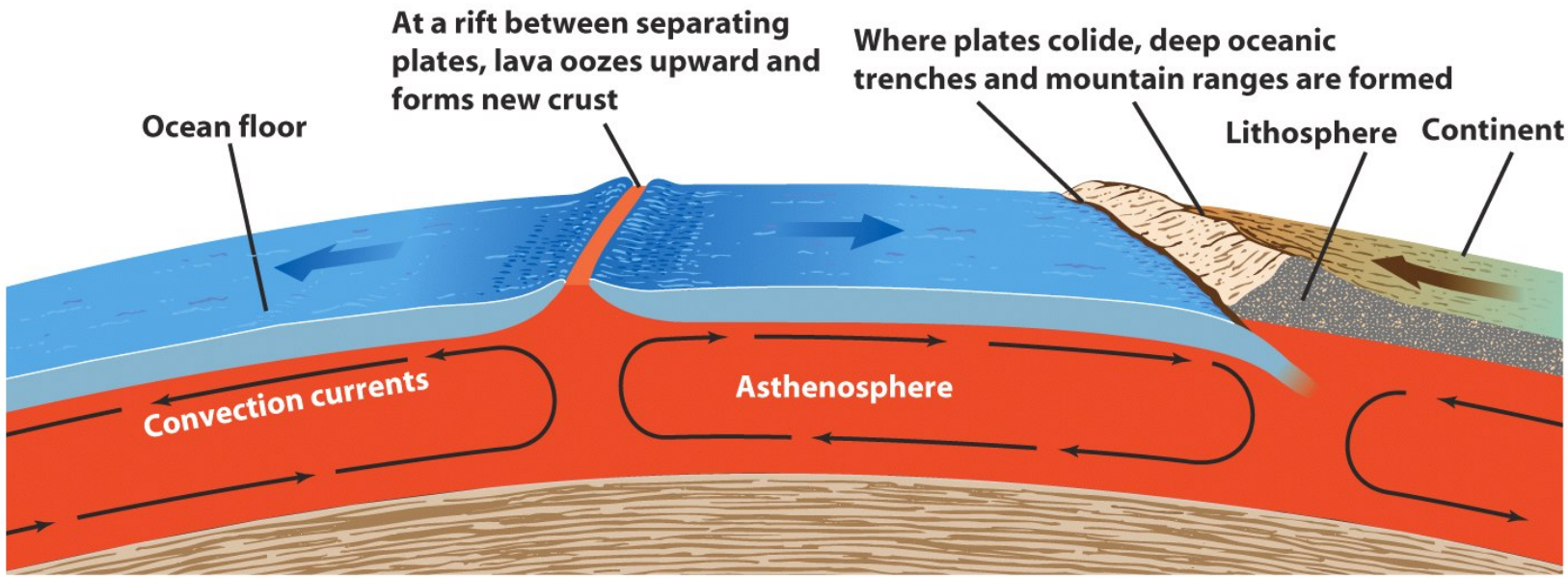


Plate Movement

- Locations of earthquakes and volcanoes mark the boundary of the moving plates, where plates separate, collide, or rub together
- **Cycle of Supercontinents**: The moving plates reassemble into a supercontinent and then break apart again, in about every 500 million years

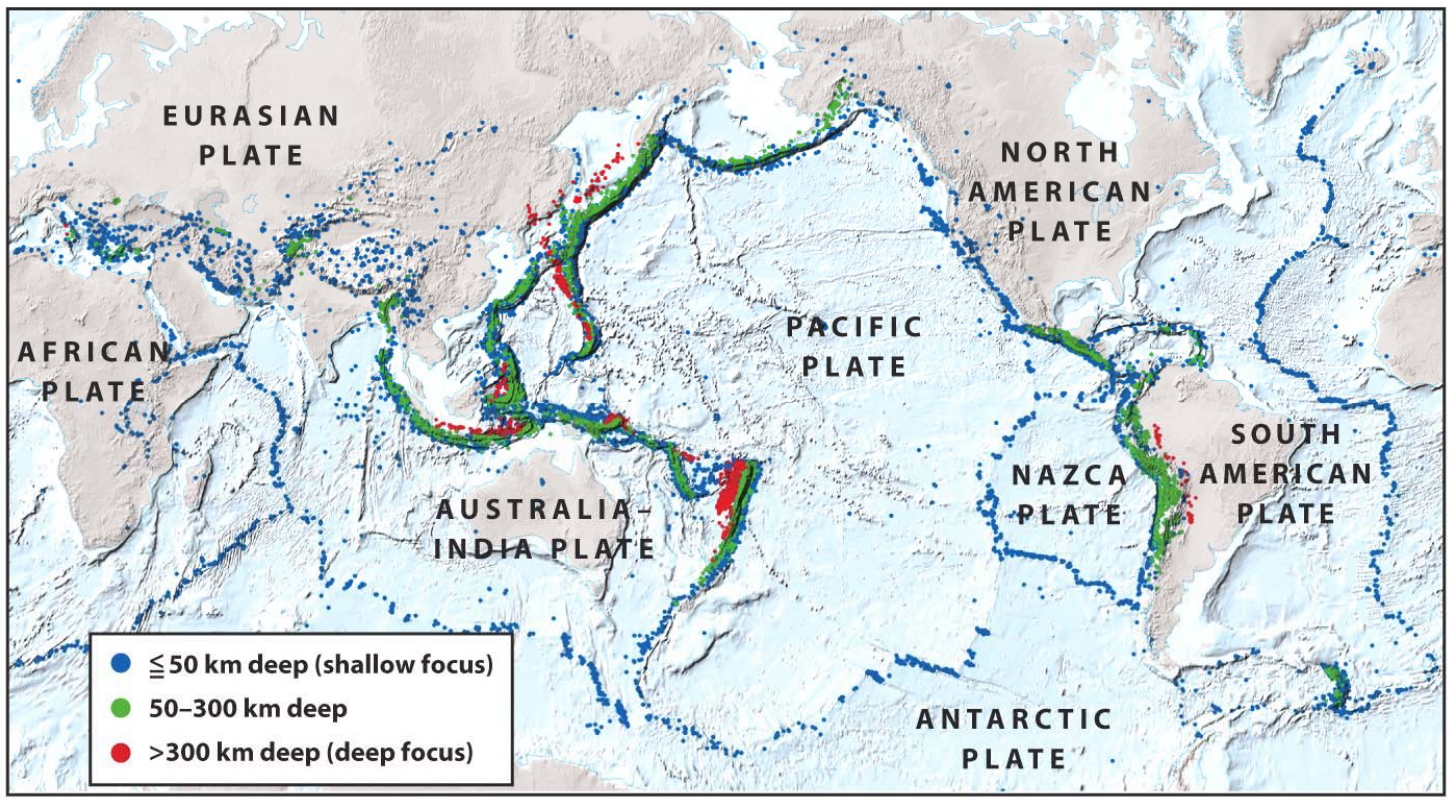
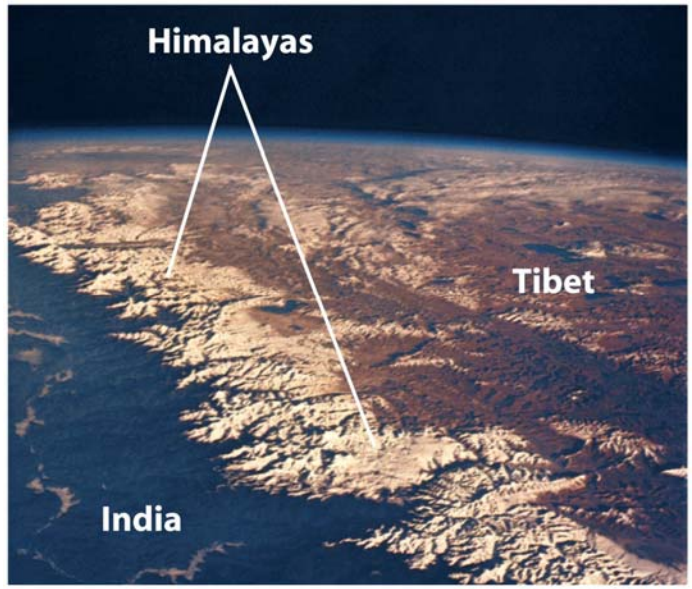


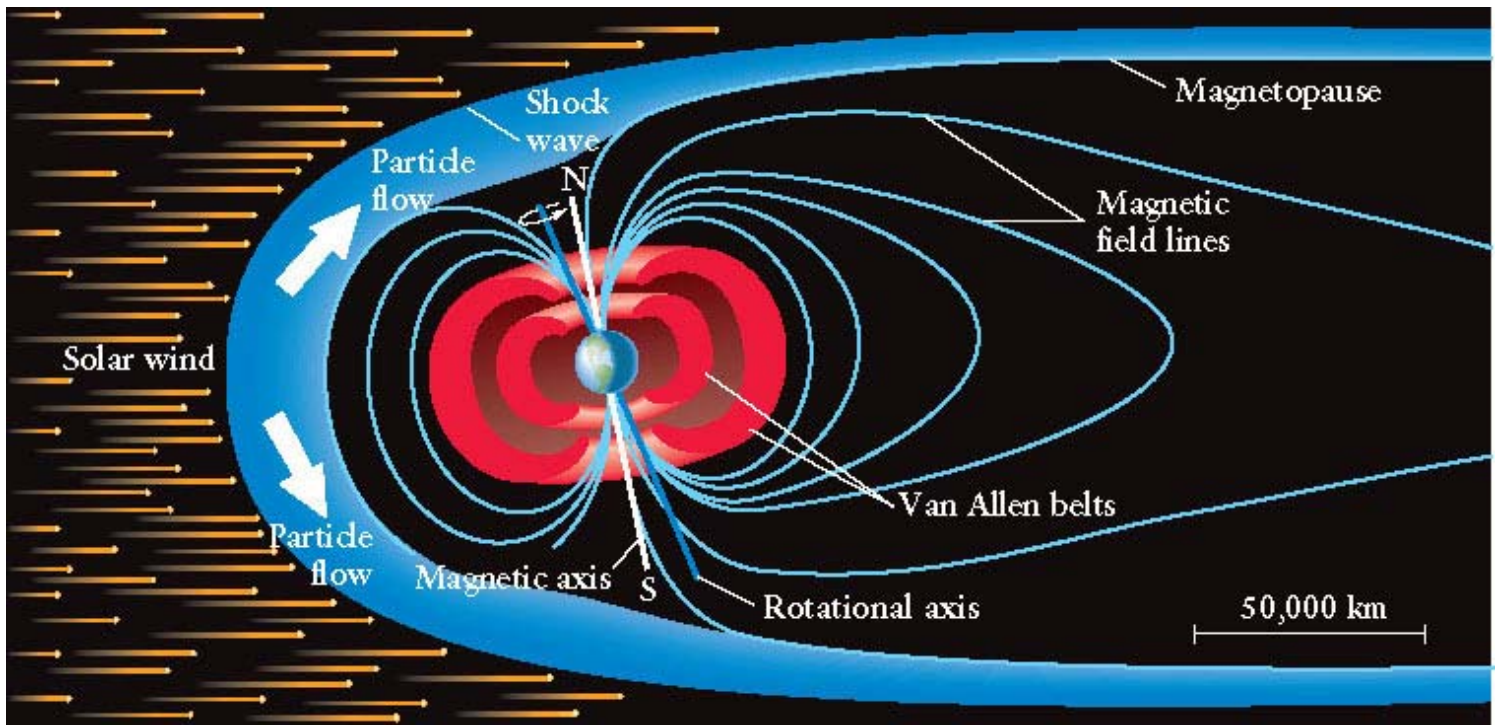
Plate Movement

- The Himalayas Mountain
  - The plates that carry India and China are colliding
  - Both plates are pushed upward, forming the highest mountains on the Earth
- Mid-Atlantic Ridge
  - Mountain ridge rises up from the floor of the North Atlantic Ocean
  - Lava seeps up from the rift



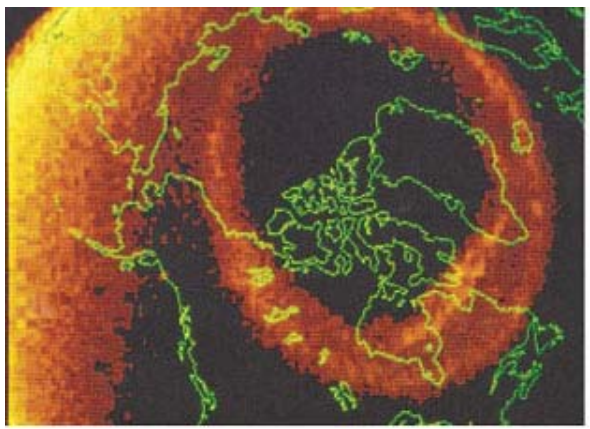
Earth's Magnetosphere

- The internal heat maintains a liquid iron core, which generates magnetic fields through the dynamo process
- This magnetic field produces a **magnetosphere** surrounding the Earth



Earth’s Magnetosphere

- Magnetosphere deflects most of the particles of the solar wind from entering the Earth’s atmosphere, thus protect the Earth from harmful particle radiation
- **Solar wind:** a continuous flow of charged particles, streaming out constantly from the Sun.
- **Aurora**: when the magnetosphere is overloaded, charged particles enter the Earth’s upper atmosphere, excites gas atoms and produce the shimmering light display



(a)

(b)

(c)

Atmosphere: Evolution

- Composition of present-day: 78% Nitrogen, 21% Oxygen, and 1% water vapor and 0.035% Carbon Dioxide
- Venus and Mars: > 95% Carbon Dioxide
- The presence of nitrogen and oxygen in the Earth's atmosphere is the result of **life on Earth**

table 9-4 **Chemical Compositions of Three Planetary Atmospheres**

	Venus	Earth	Mars
Nitrogen (N_2)	3.5%	78.08%	2.7%
Oxygen (O_2)	almost zero	20.95%	almost zero
Carbon dioxide (CO_2)	96.5%	0.035%	95.3%
Water vapor (H_2O)	0.003%	about 1%	0.03%
Other gases	almost zero	almost zero	2%

Atmosphere: Evolution

- During the early time, the Earth's atmosphere was primarily water vapor, which formed liquid water as Earth cooled
- The atmosphere was then mainly $CO_{2,}$, produced by volcanic eruptions, a process called "**outgassing**"
- $CO_{2,}$ dissolves in rainwater and falls into the oceans
- They combines with other substances to form a class of minerals called carbonates.
- These carbonates form sediments on the ocean floor, which are eventually recycled into the crust by subduction
- This "outgassing-carbonating" carbon-cycle maintains the level of CO_2 in the atmosphere.

Atmosphere: Evolution

- The appearance of life radically transformed the atmosphere.

•Photosynthesis

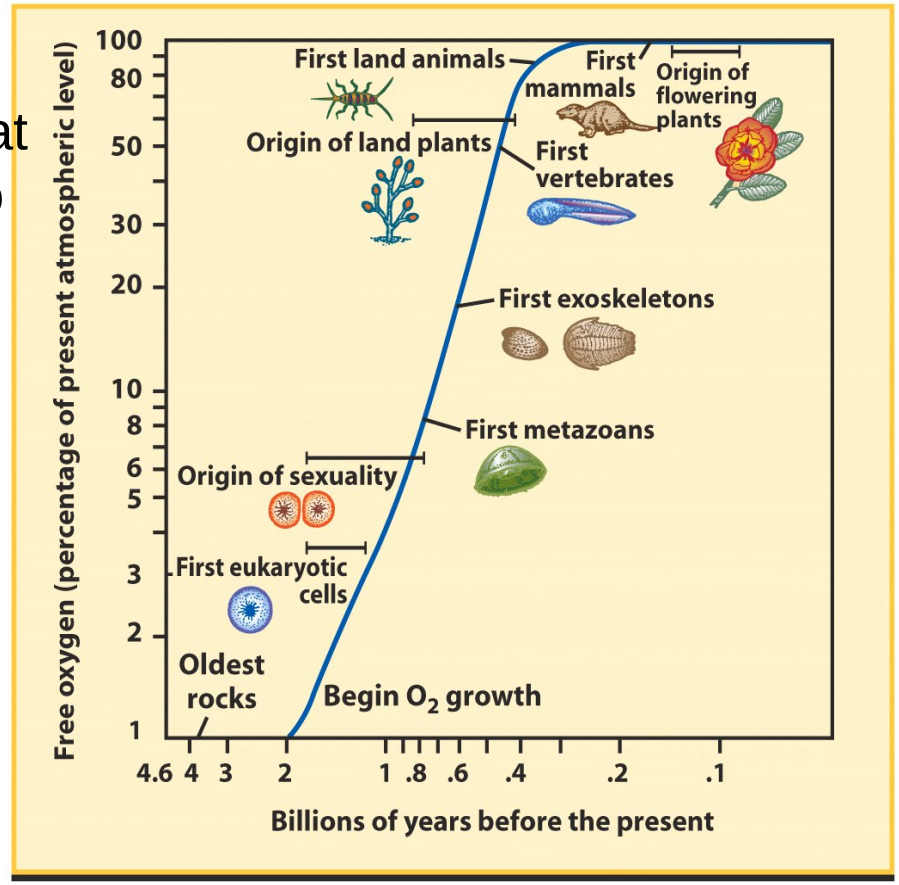
- A chemical process by **plants** that converts energy from sunlight into chemical energy
- It consumes CO_2 and water and release oxygen (O_2)
- **O_2 accumulates in the atmosphere with time**

•Respiration

- Animals consume O_2 and release CO_2

•Eventually, O_2 level stabilized at 21%

•N_2 are produced by bacteria that extract energy from nitrate minerals



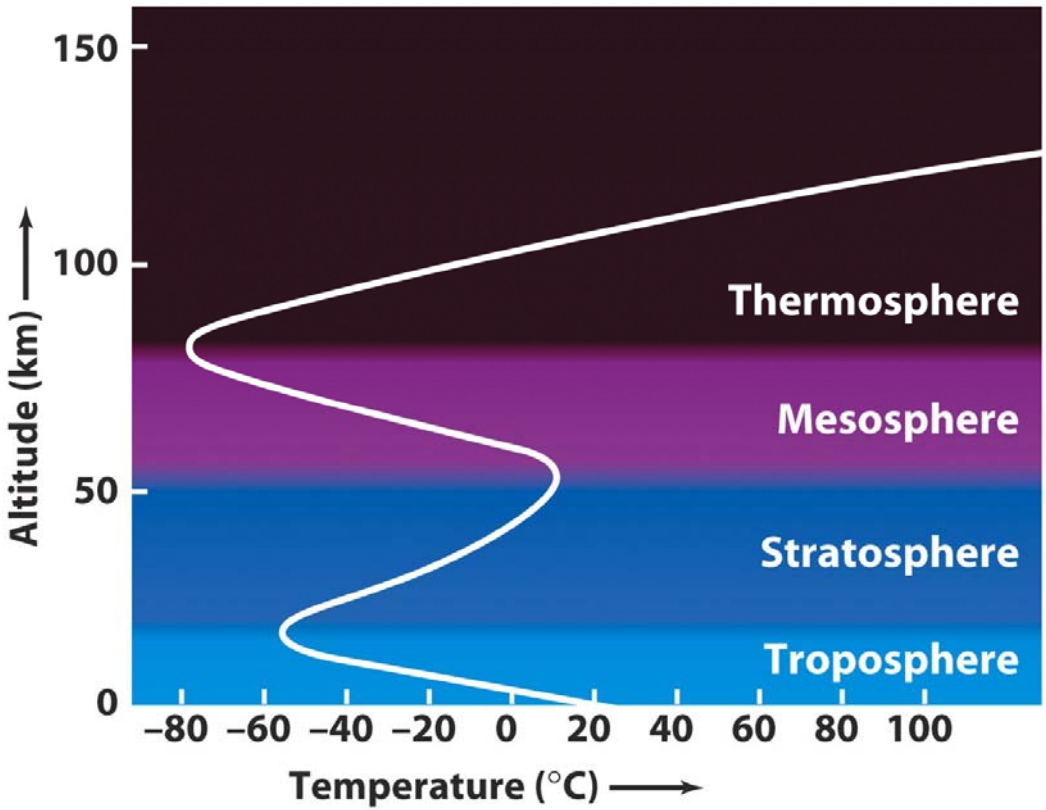
Earth's Atmosphere: Structure

- Based on temperature profile, the Earth's atmosphere is divided into layers called the **troposphere, stratosphere,** mesosphere, and thermosphere

•Troposphere: 0 – 12 km

• Temperature decreases with increasing altitude, because the sunlight heats the ground and upper part remains cool

•This temperature profile in troposphere causes convection currents up and down, resulting in all of the Earth's weather

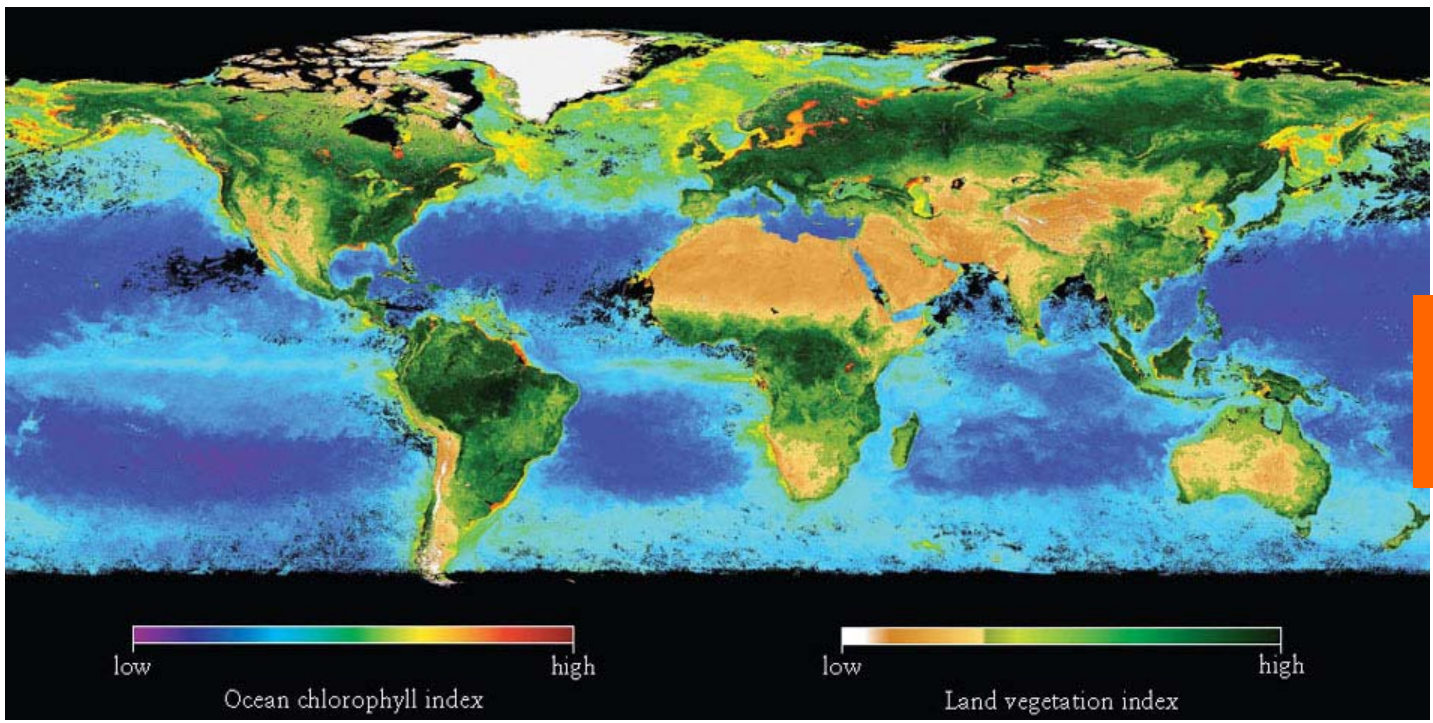


Earth's Atmosphere: Structure

- **Stratosphere:** 12 – 50 km
  - Temperature increases with increasing altitude
  - Temperature increases because an appreciable amount of ozone (O_3) in this layer direct absorb ultraviolet from the Sun
  - This temperature profile does not allow any convection in the stratosphere
- **Mesosphere:** temperature decreases again with increasing height, because little ozone exists there
- **Thermosphere:** temperature increases with altitude, because the present of individual oxygen and nitrogen directly absorb extremely short ultraviolet light from the Sun

Earth's Biosphere

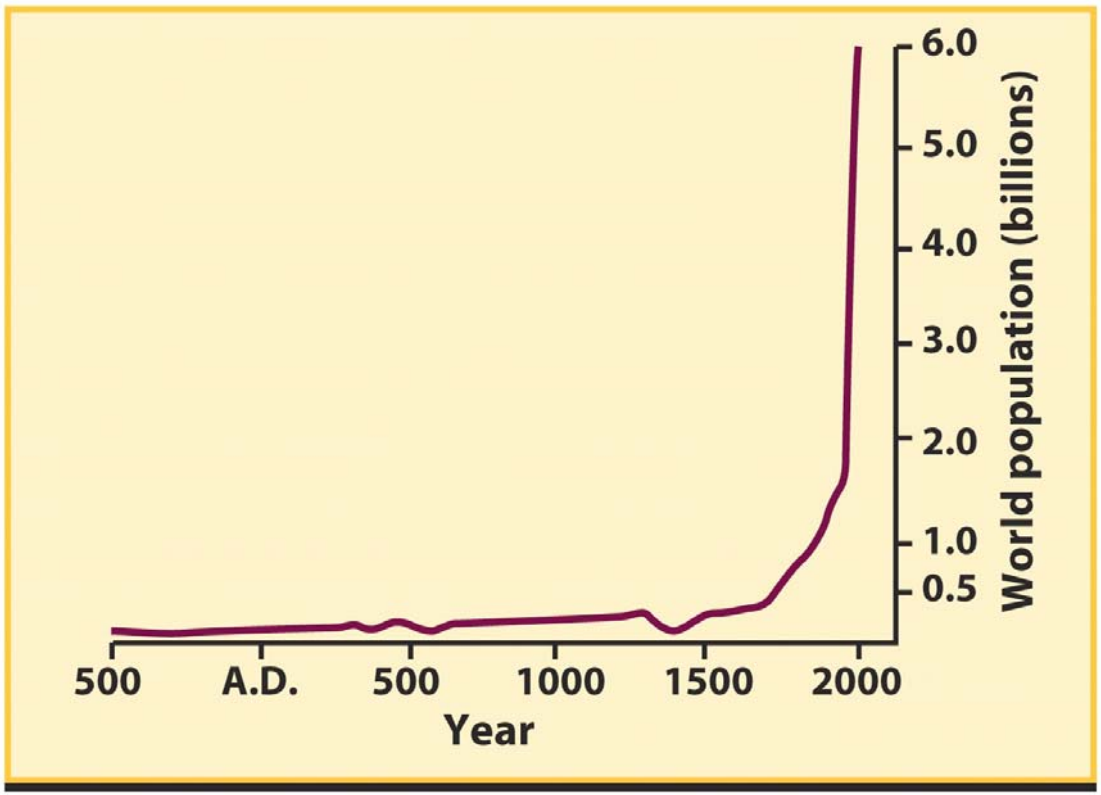
- **Biosphere:** the thin layer enveloping the Earth where all living organisms reside, including
  - The oceans
  - The lowest few kilometers of the troposphere
  - The crust to a depth of almost 3 kilometers



Plant Distribution

Earth's Biosphere

- Human population began to rise in late 1700s with the industrial revolution
- The rise accelerated in the 20th century thanks to medical and technological advances such as antibiotics.

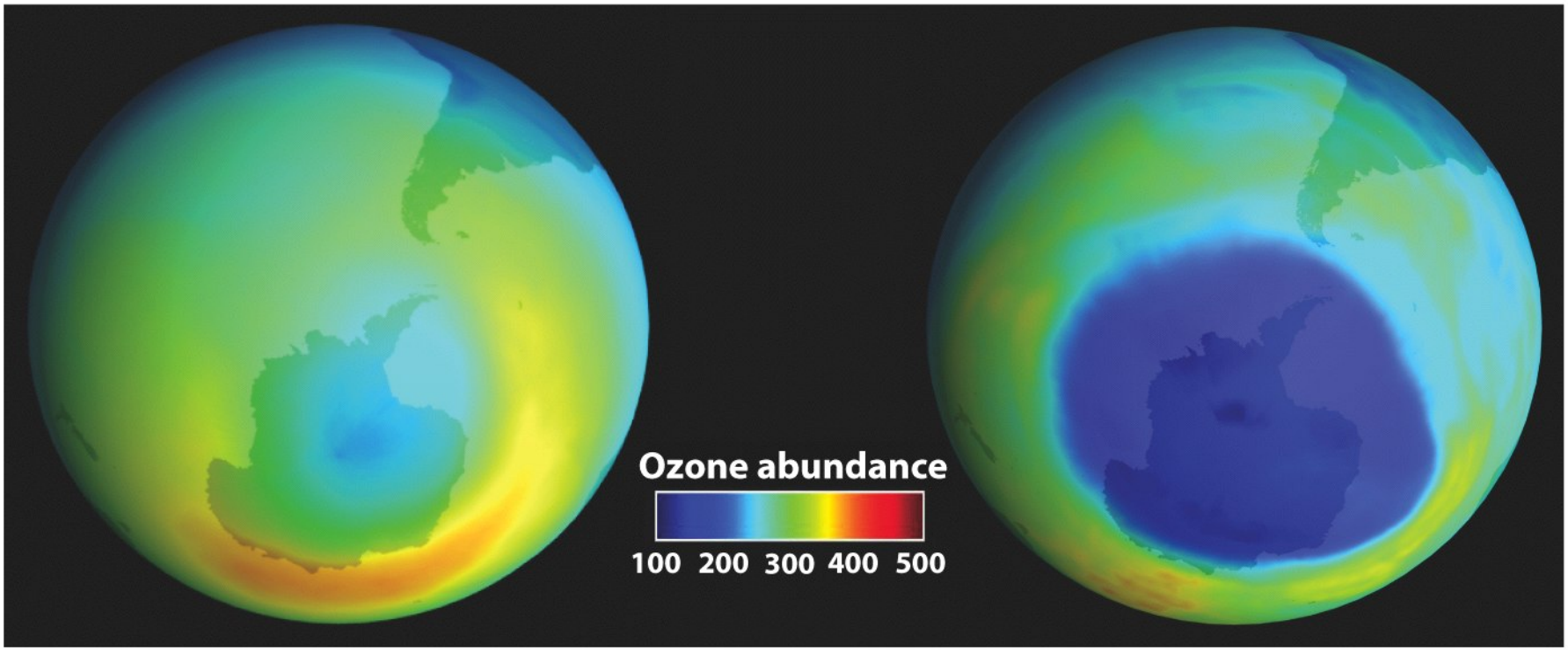


Human Population

- On the land, human activities resulted in deforestation.

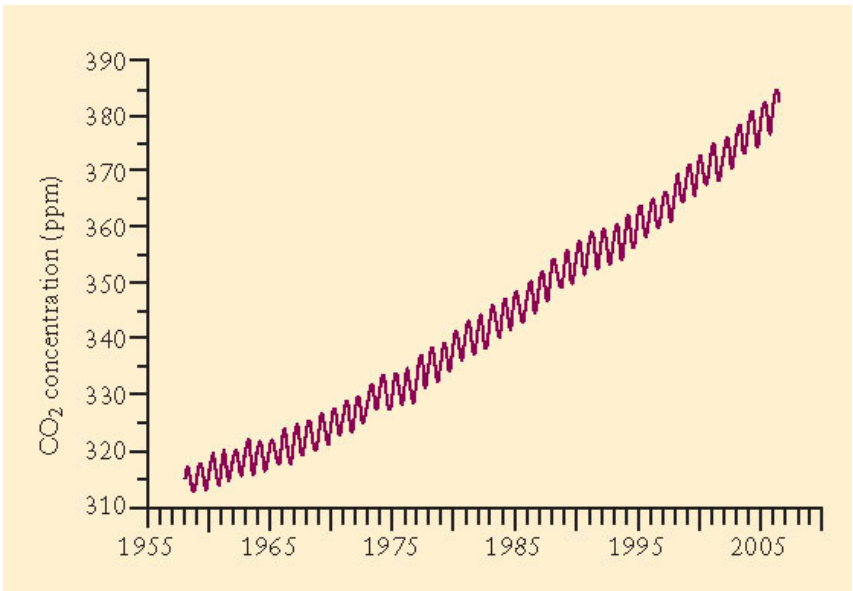
Earth's Biosphere

- **Ozone hole**: a region with an abnormally low concentration of ozone
- Ozone can be destroyed by industrial chemicals (CFCs)
- There has been worldwide increase in the number of deaths due to skin cancer caused by solar UV radiation

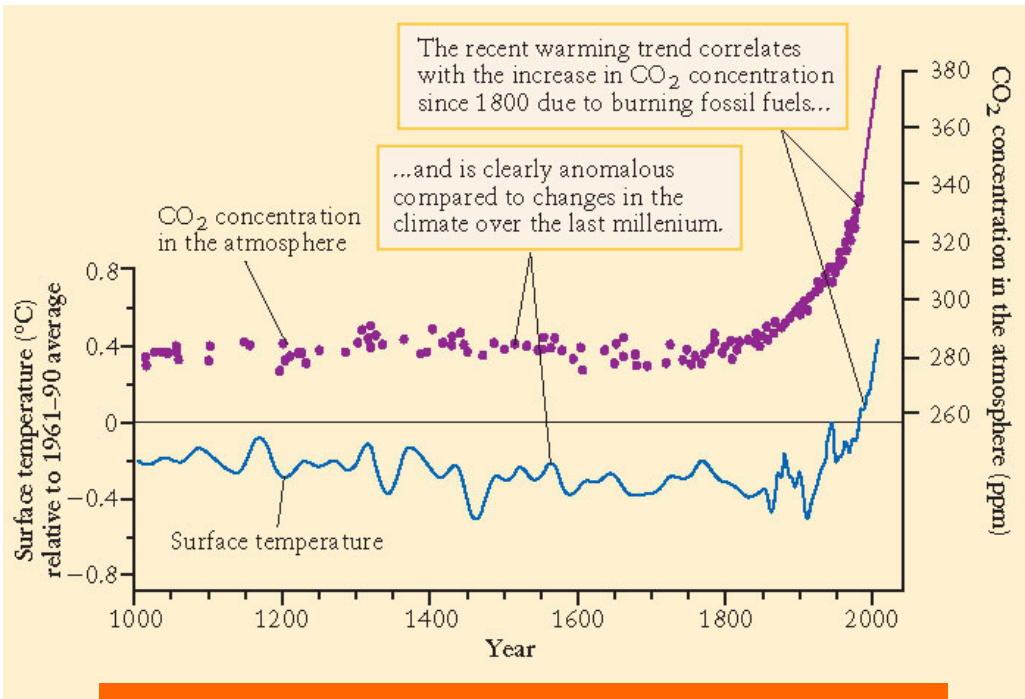


Earth's Biosphere

- **Global warming**: a warming trend of global temperature in the past 140 years. It is predicted to continue to rise.
- It is **"partially"** due to the industrial release of greenhouse gas such as CO2, by burning fossil feuls (petroleum and coal)



CO_2 increases 21% since 1958



Temperature has increased <1°C since 1800, but accelerates

Final Notes on Chap. 9

- All 7 sections are covered.