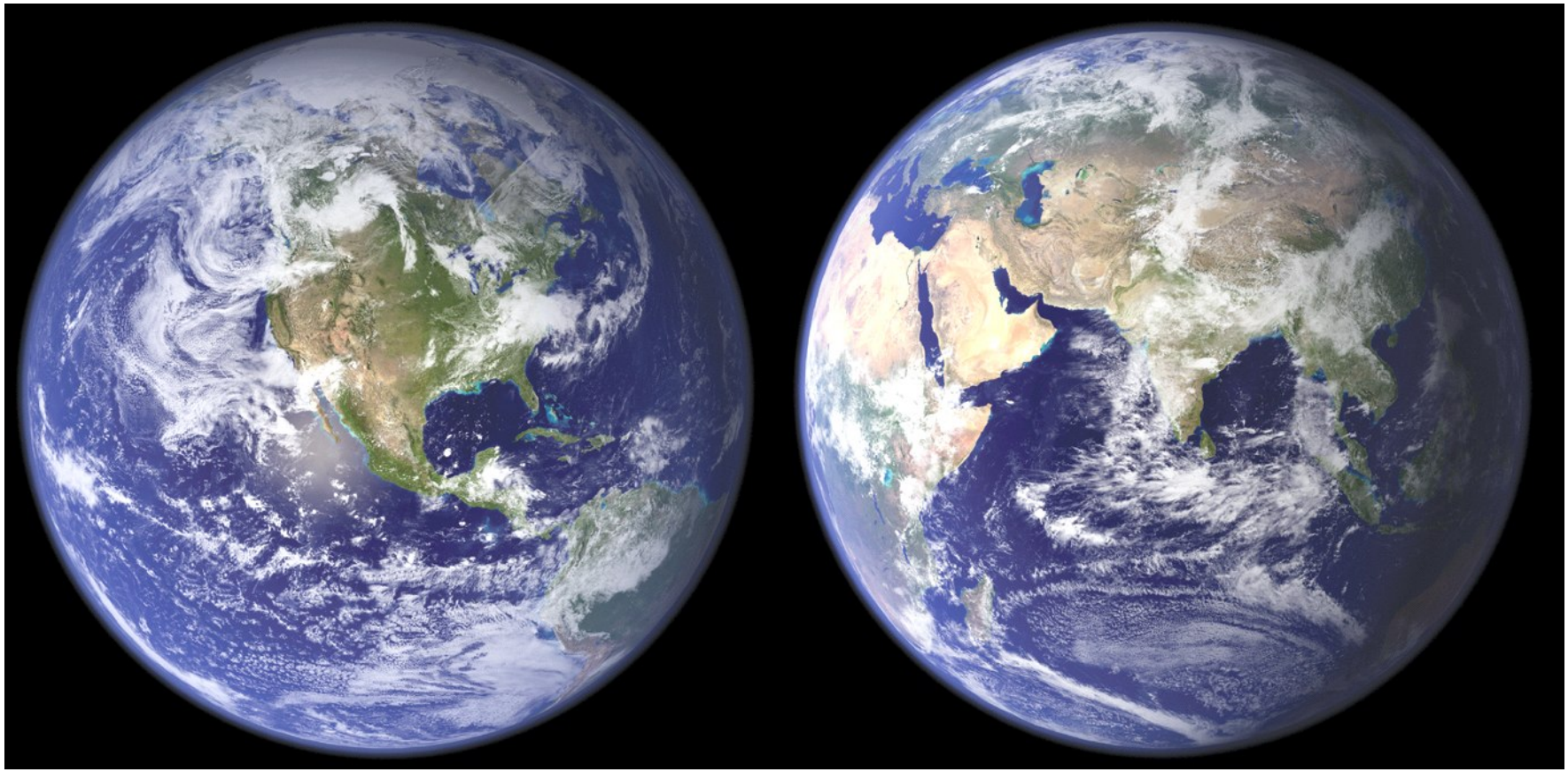
The Living Earth



Chapter Nine

ASTR 111 – 003 **Fall 2006**
Lecture 09 Oct. 30, 2006

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II

Ch9: The Living Earth

Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn
Ch16: Outer World
Ch17: Vagabonds of Solar System

Guiding Questions

1. What is the greenhouse effect? How does it affect the average temperature of the Earth?
2. Is the Earth completely solid inside? How can scientists tell?
3. How is it possible for entire continents to move across the face of the Earth?
4. How does our planet's magnetic field protect life on Earth?
5. Why is Earth the only planet with an oxygen-rich atmosphere?
6. Why are prevailing winds generally from the west over most of North America but generally from the east in Hawaii?
7. What are global warming and the "ozone hole"? Why should they concern us?

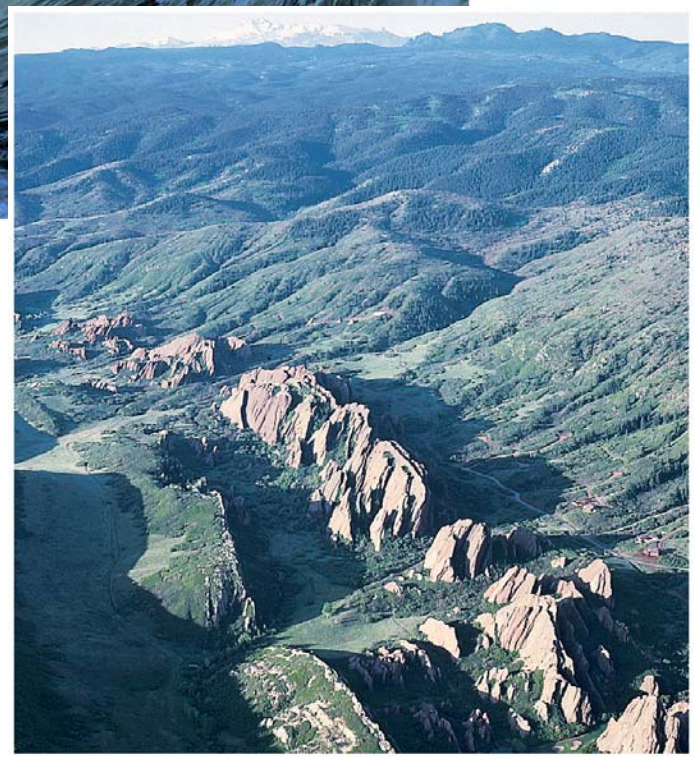
Earth Data

table 9-1 | Earth Data

Average distance from the Sun:	1.000 AU = 1.496×10^8 km
Maximum distance from the Sun:	1.017 AU = 1.521×10^8 km
Minimum distance from the Sun:	0.983 AU = 1.471×10^8 km
Eccentricity of orbit:	0.017
Average orbital speed:	29.79 km/s
Orbital period:	365.256 days
Rotation period:	23.9345 hours
Inclination of equator to orbit:	23.45°
Diameter (equatorial):	12,756 km
Mass:	5.974×10^{24} kg
Average density:	5515 kg/m^3
Escape speed:	11.2 km/s
Albedo:	0.39
Surface temperature range:	Maximum: 60°C = 140°F = 333 K Mean: 14°C = 57°F = 287 K Minimum: −90°C = −130°F = 183 K
Atmospheric composition (by number of molecules):	78.08% nitrogen (N_2) 20.95% oxygen (O_2) 0.035% carbon dioxide (CO_2) about 1% water vapor

An Active Earth

- Active Atmosphere
- Active Ocean
- Active Land



An Active Earth

- All activity in the Earth is powered by three sources of energy
    1. Solar energy
    2. Tidal forces (from Sun and Moon's gravity)
    3. Earth's internal heat (left over from the creation)

•Atmosphere is powered by solar energy

•Ocean is powered by solar energy and tidal forces

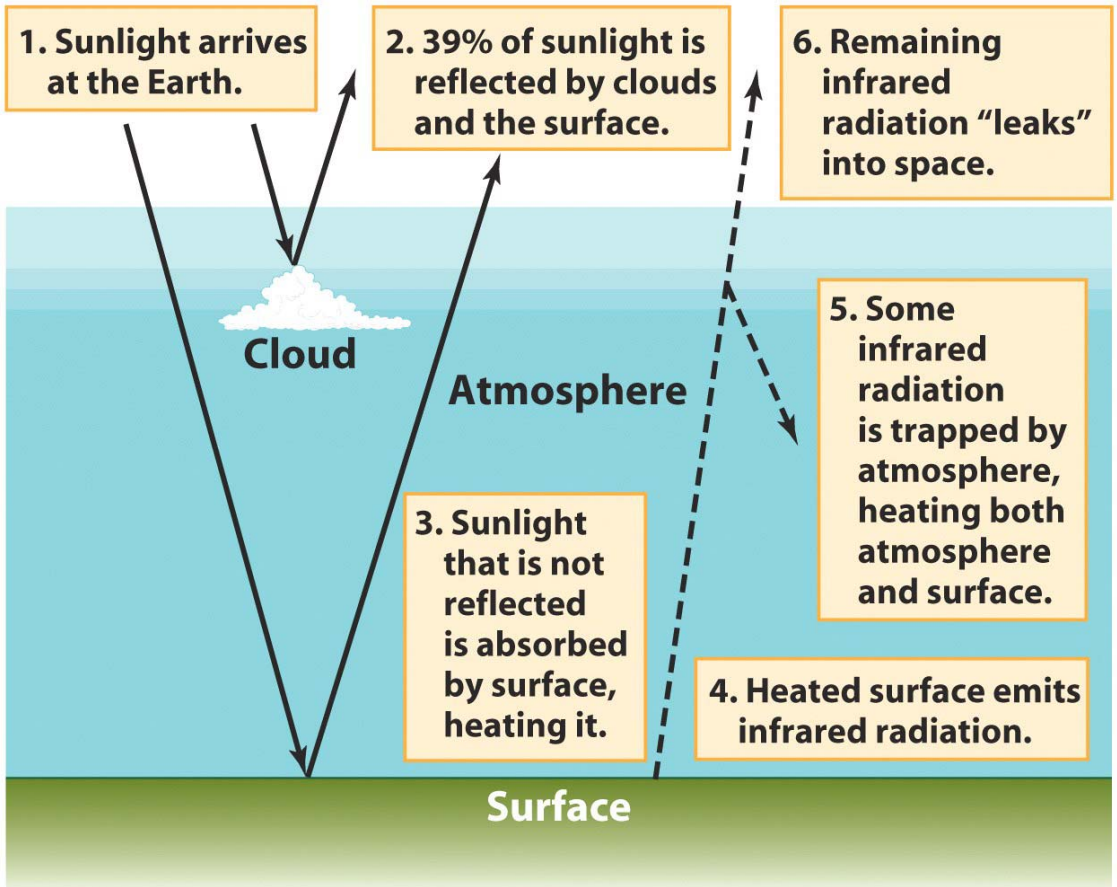
•Land is powered by the internal heat

table 9-2 The Earth's Energy Sources

Activity	Energy Sources
Motion of water in oceans, lakes, rivers	Solar energy, tidal forces
Motion of the atmosphere	Solar energy
Reshaping of surface	Earth's internal heat
Life	Solar energy (a few species that live on the ocean floor make use of the Earth's internal heat)

The 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

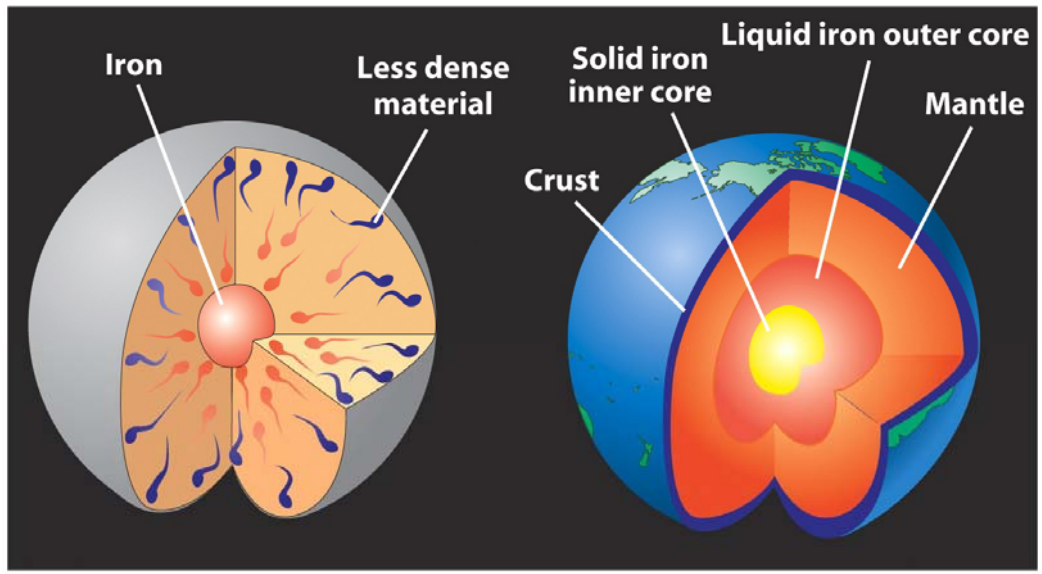


The Greenhouse Effect

- The Earth's surface is directly heated by the radiation from the Sun, because the atmosphere is almost transparent to the visible light
- The Earth's surface emits infrared radation
- The CO_2 gas and H_2O water vapor, so called greenhouse gases in the atmosphere, strongly absorb the infrared radiation, thus trap the solar energy
- The greenhouse effect raises the Earth's surface temperature by 41°C
  - The average actual surface temperature is 14°C
  - If no greenhouse effect, the calculated surface temperature would be about -27°C

Earth's interior structure

- Earth has a layered internal structure, due to chemical differentiation process in the early time
  - 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

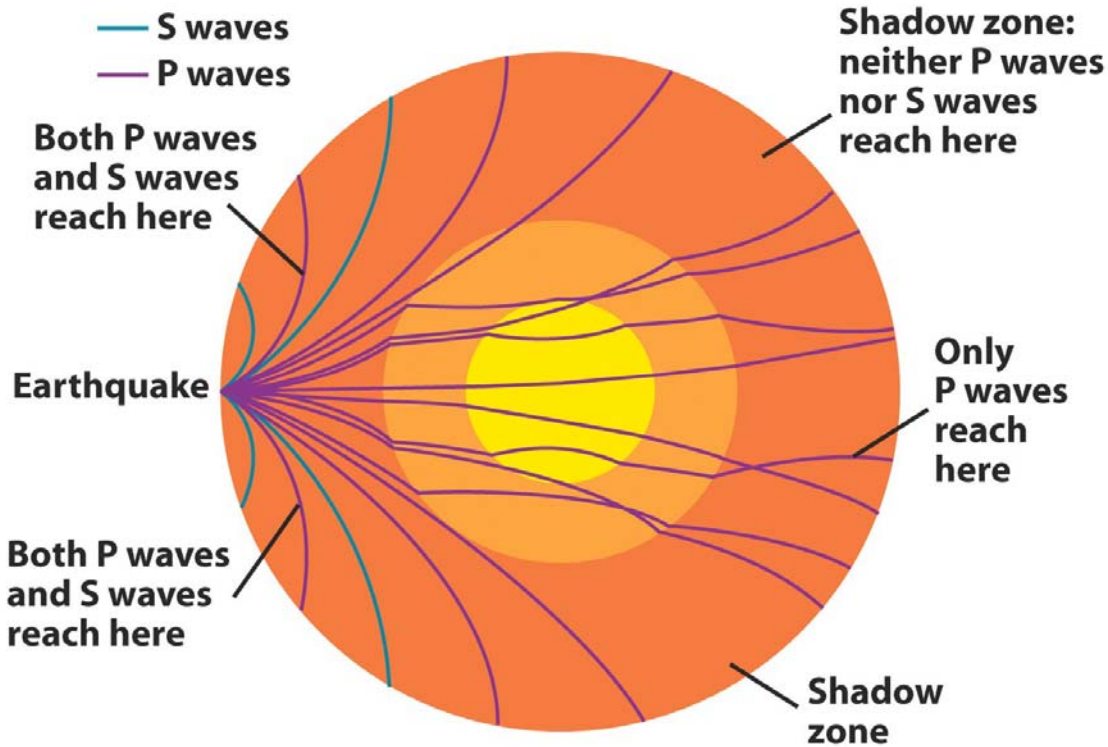
Earth's interior structure

- Present-day Earth has three layers: crust, mantle and core
- Crust: 5 km to 35 km deep, solid, made of relatively light silicon-rich minerals
- Mantle: 2900 km deep, solid, made of relatively heavy iron-rich minerals
- Core: 2900 km – 6400 km deep, made of pure iron
  - Outer core: 2900 km – 5100 km deep, liquid
  - Inner core: 5100 km – 6400 km deep, solid

Region	Depth below surface (km)	Distance from center (km)	Average density (kg/m^3)
Crust (solid)	0–5 (under oceans) 0–35 (under continents)	6343–6378	3500
Mantle (solid)	from bottom of crust to 2900	3500–6343	3500–5500
Outer core (liquid)	2900–5100	1300–3500	10,000–12,000
Inner core (solid)	5100–6400	0–1300	13,000

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 as they pass through different part of the Earth’s interior



Earth's interior structure

- From surface to center, temperature (as well as pressure) rises steadily from 14°C to 5000°C
- The state depends on the actual temperature relative to the melting temperature
  - Melting temperature is determined by chemical composition and pressure
  - The mantle is primarily solid because the temperature there is lower than the melting point
  - The outer core is liquid, because the temperature there is higher than the melting point

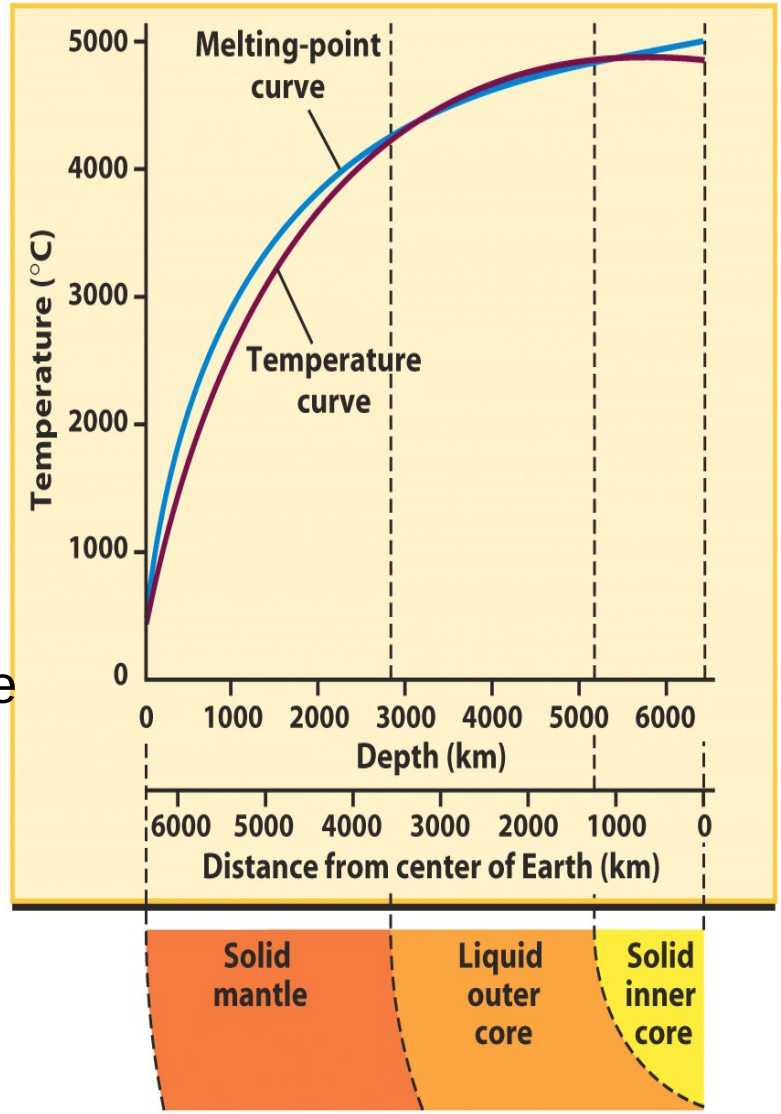


Plate Tectonics

- The world map indicates that the continents would fit rather snugly against each other.
- Alfred Wegener, in 1915, suggested the idea of “continental drift”.
- All continents have originally been a single gigantic supercontinent, called Pangaea (meaning “all lands”)

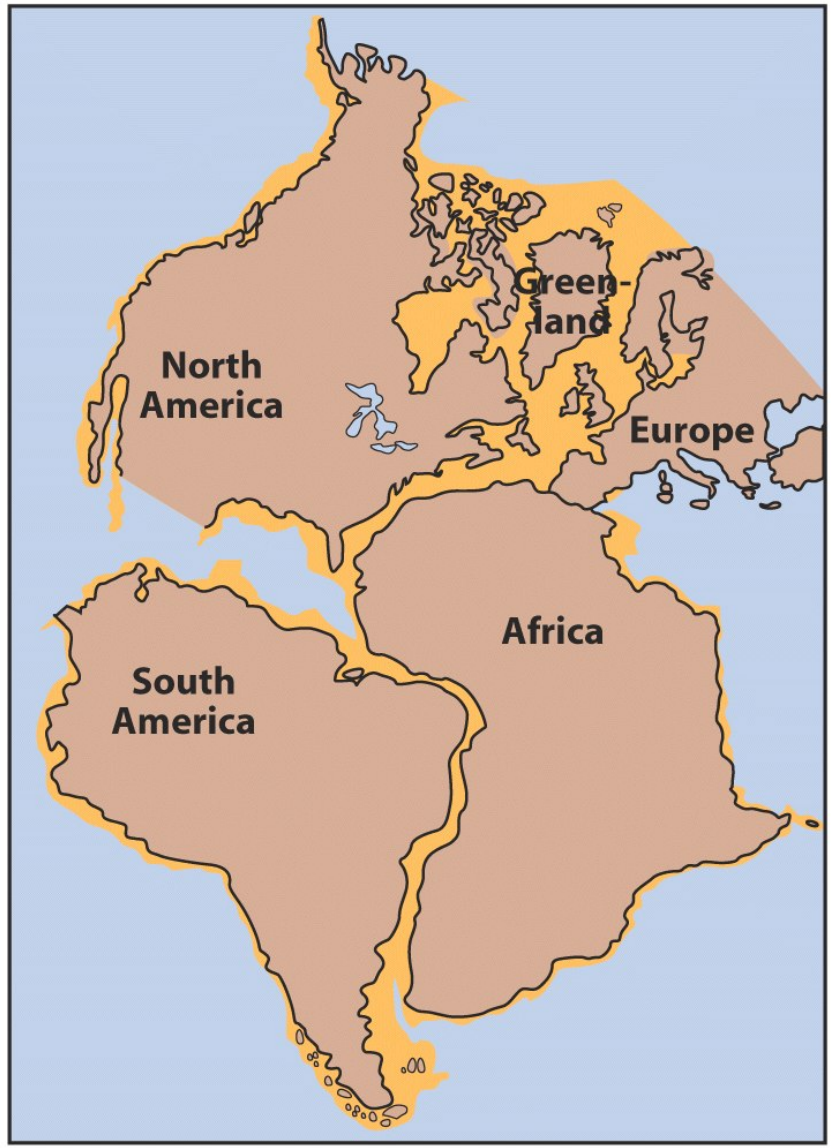


Plate Tectonics

- About 200 million year ago, almost all continents were merged into a single supercontinent, called Pangaea

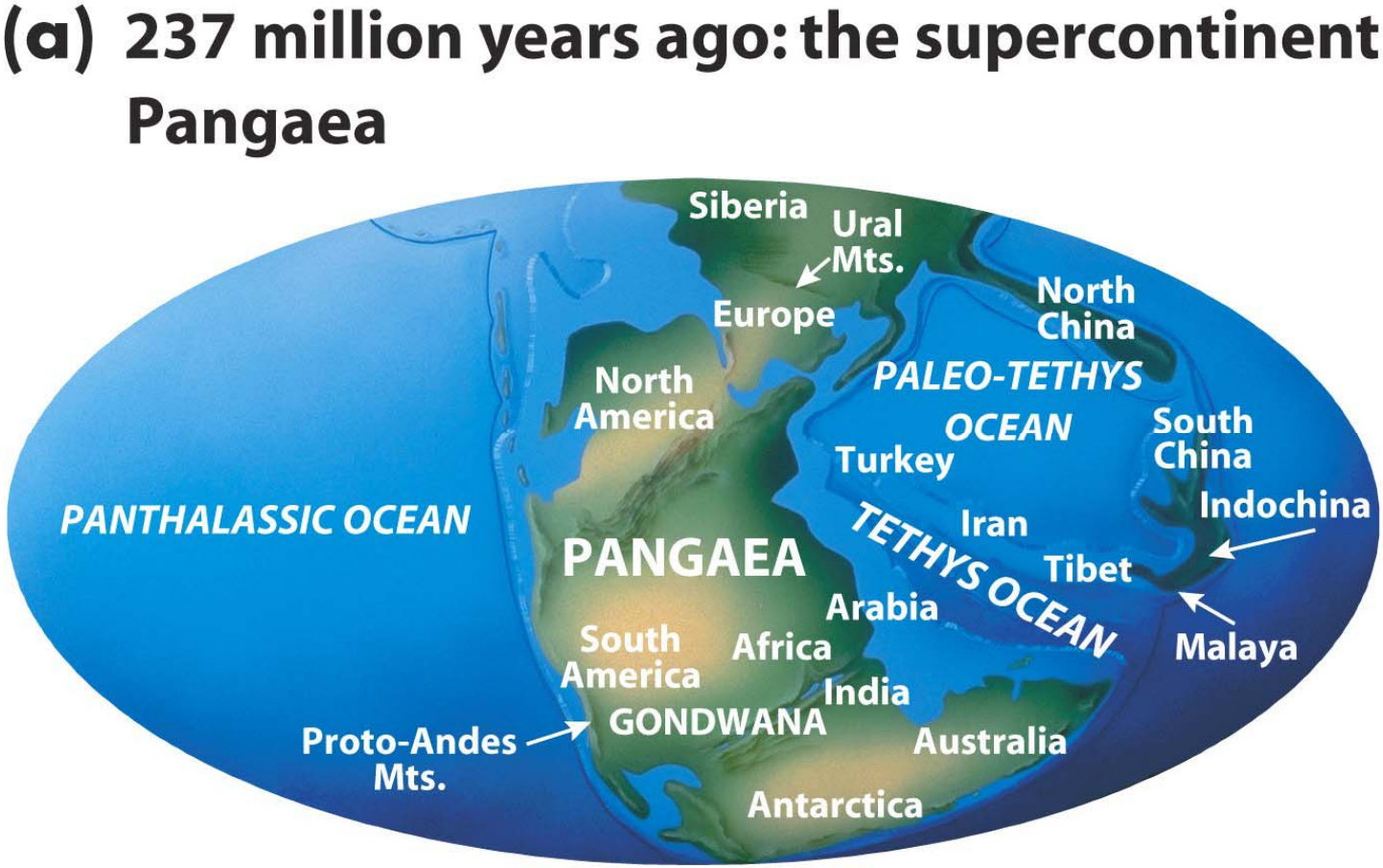


Plate Tectonics

- Pangaea first split into two smaller continents, Laurasia in the north, and Gondwana in the south

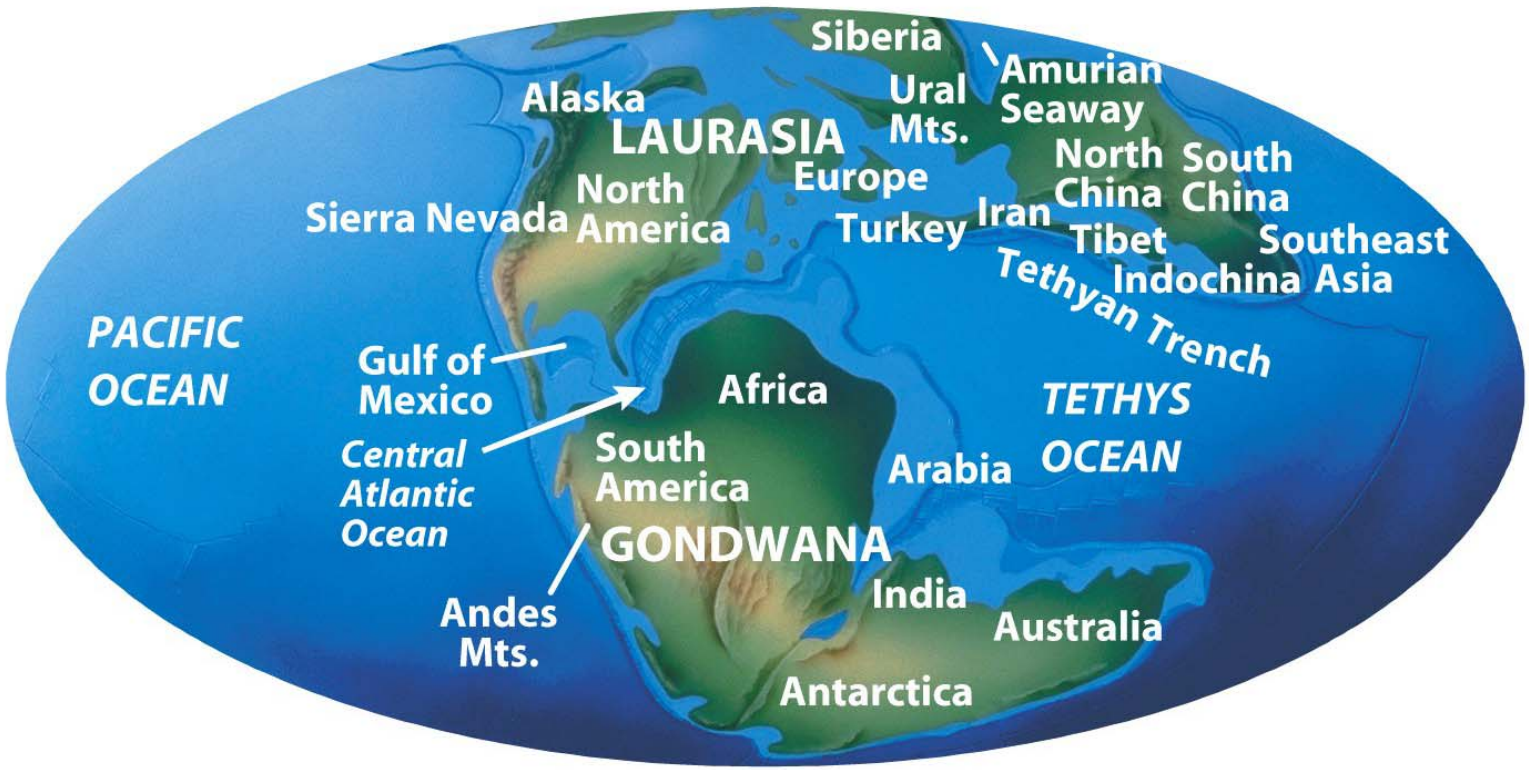


Plate Tectonics

- The continental drifting speed is several cm per year
  - For example, at a rate of 3 cm/year over 200 million years, the drifting distance is 6000 km

(c) The continents today

Plate Tectonics

- Plate tectonics is caused by the internal heat of the Earth
- **Asthenosphere** is the upper levels of the mantle that are hot and soft enough to permit a plastic flow.
- 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
- As one end of a plate is subducted back into the asthenosphere, it helps to pull the rest of the plate along

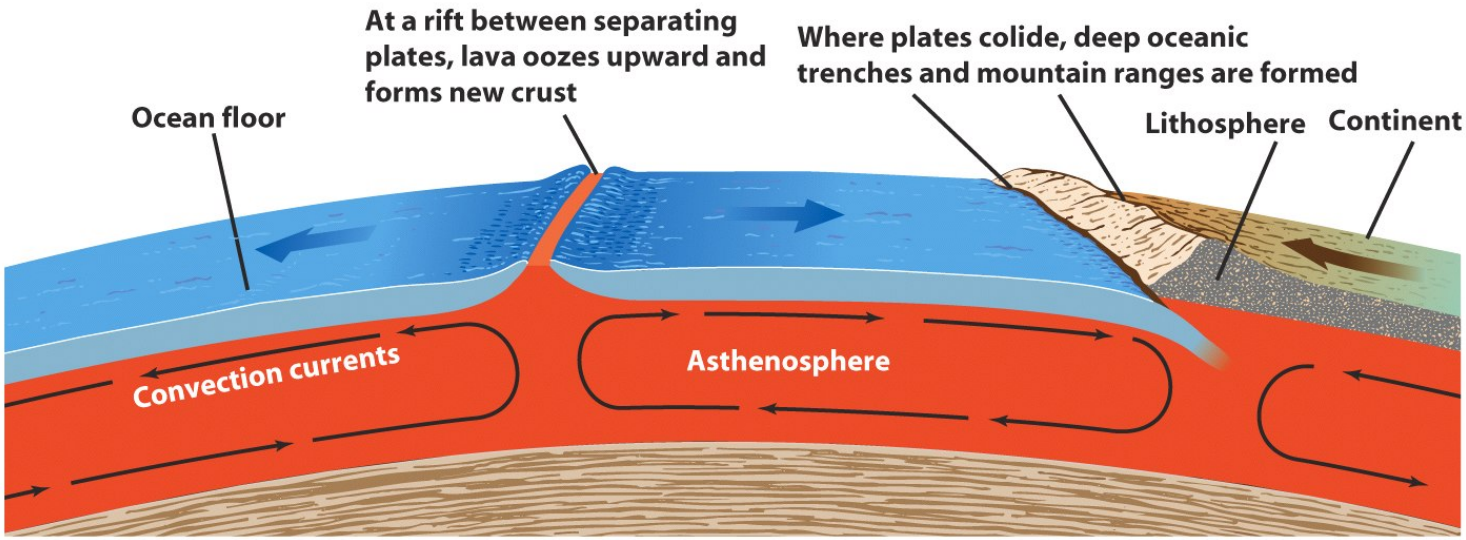


Plate Tectonics

- The Earth's crust and a small part of its upper mantle form a rigid layer called the **lithosphere.**
- The lithosphere is divided into plates that move over the plastic layer called the asthenosphere in the upper mantle
- Most earthquakes occur where plates separate, collide, or rub together; plate boundaries are identified by plotting earthquake epicenters

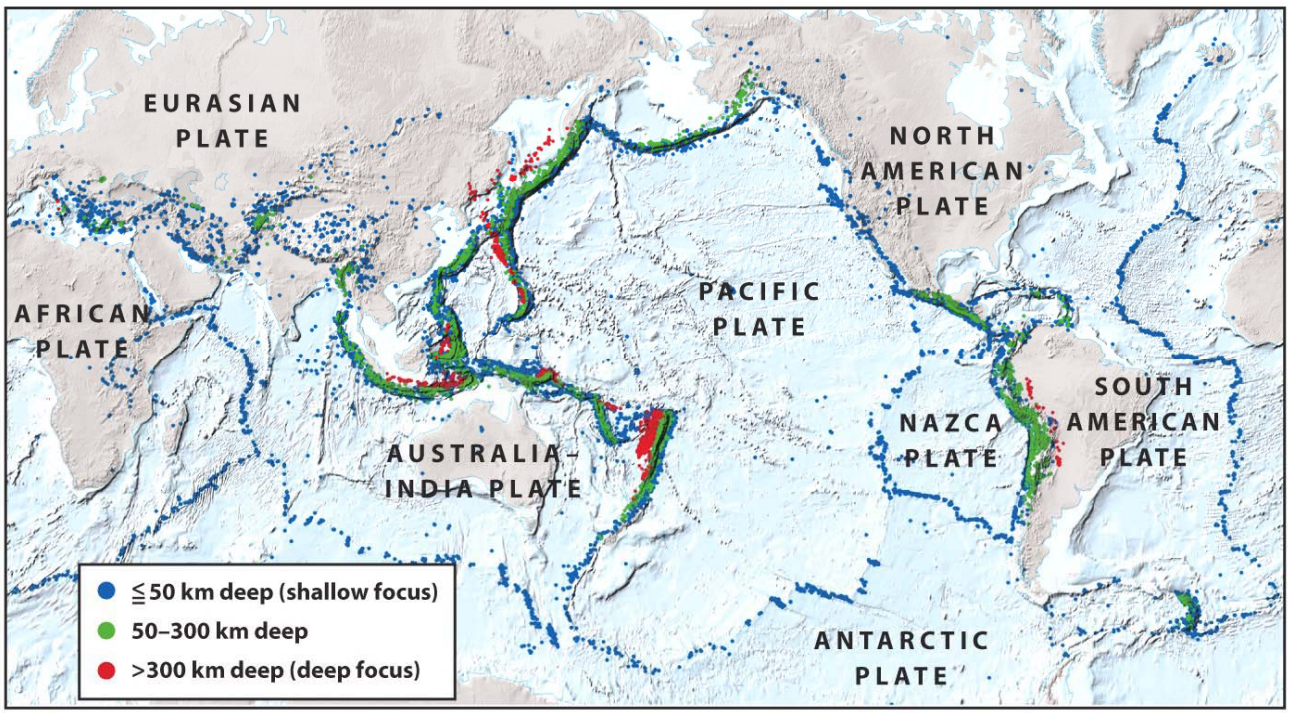
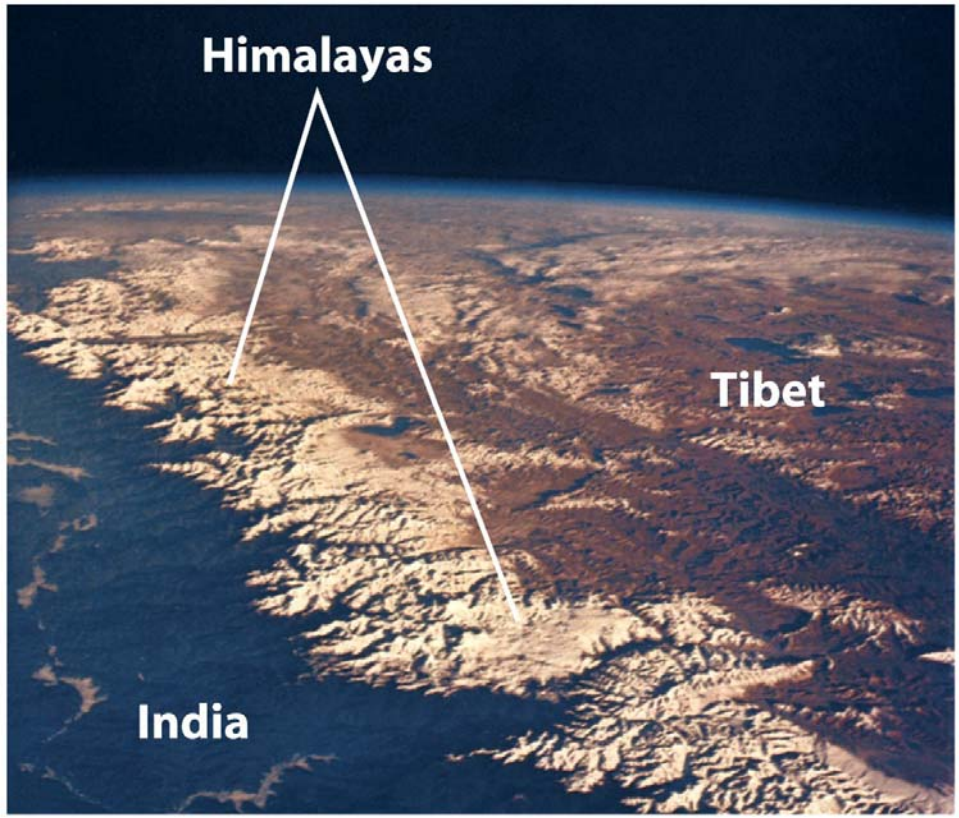


Plate Tectonics

- The Mid-Atlantic Ridge
  - Lava seeps up from the Earth's interior along a rift extends from Iceland to Antarctica
  - The upwelling motion of lave forces the existing crusts apart, causing **seafloor spreading**
  - As a result, South America and Africa are moving apart at a speed of 3 cm per year

Plate Tectonics

- The Himalayas Mountain
  - The plates that carry India and China are colliding
  - Both plates are pushed upward, forming the highest mountains on the Earth

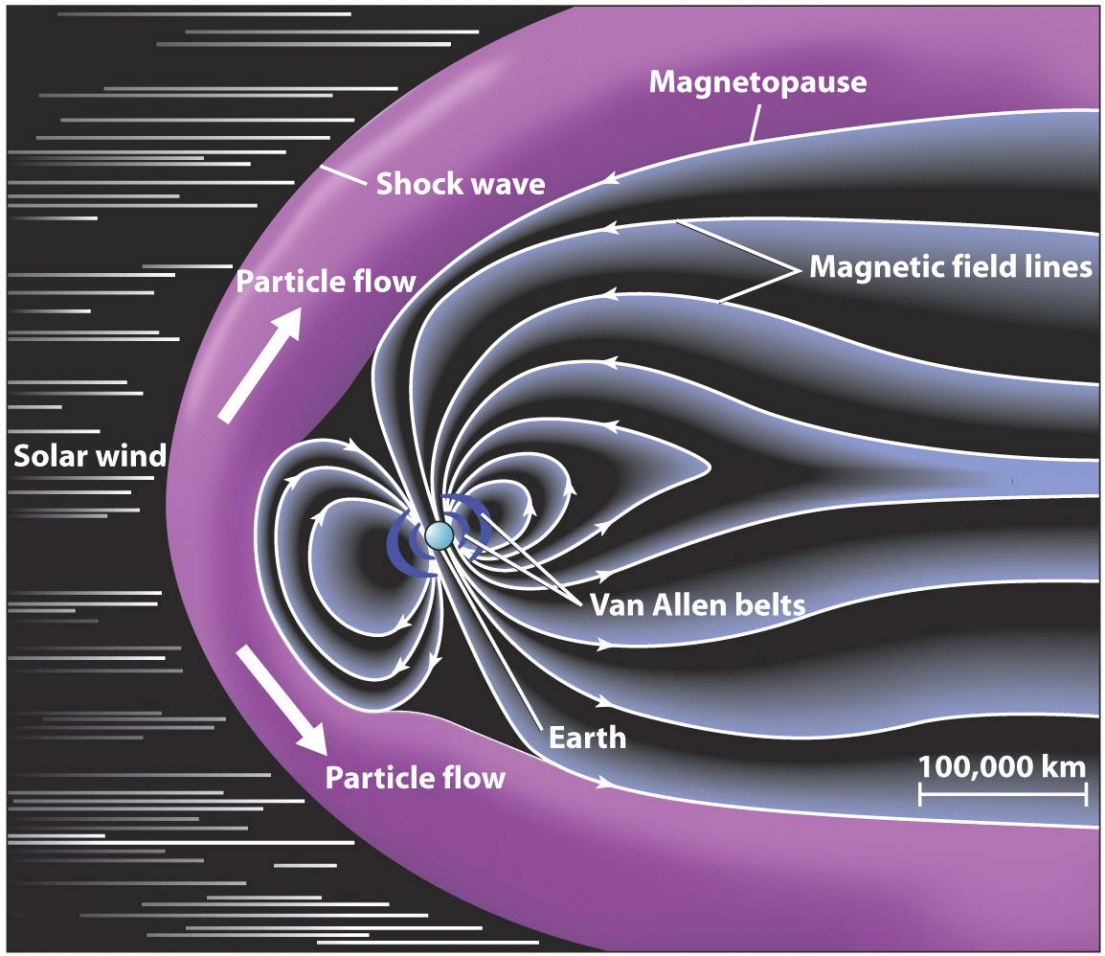


Earth’s Magnetosphere

- The motion of the liquid iron core of the Earth, which carries electric currents, generates magnetic fields
- This magnetic field produces a **magnetosphere** that surrounds the Earth
- **Magnetosphere**: the region of space around a planet in which the motion of charged particles is dominated by the planet’s magnetic field
- **Solar wind:** a continuous flow of charged particles, mostly protons and electrons, streaming out constantly from the Sun. Near the Earth, the solar wind speed is about 450 km/s

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



Earth’s Magnetosphere

- During the period of enhanced solar activity, the magnetosphere may be overloaded with changed particles
- Charged particles leak through the magnetic field and move down, collide with atoms in the upper atmosphere and cause the shimmering light display called **“aurora”**

Earth's Atmosphere: Composition

- The Earth's atmosphere differs from those of the other terrestrial planets in its chemical composition, temperature profile and circulation pattern
- Composition of present-day: 78% Nitrogen, 21% Oxygen, and 1% water vapor and carbon dioxide (greenhouse gas)
- The composition of atmosphere has evolved with time due to presence of living organims

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%

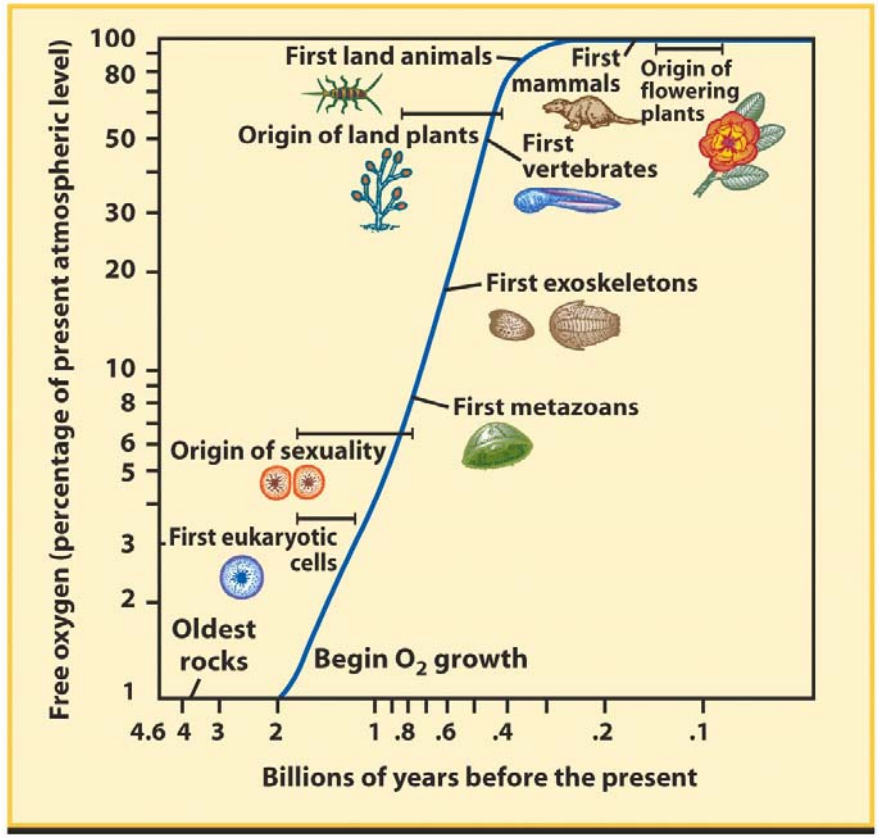
Earth's Atmosphere: Composition

- During the early time, the Earth's atmosphere is primarily CO_2, produced by volcanic eruptions.
- 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)

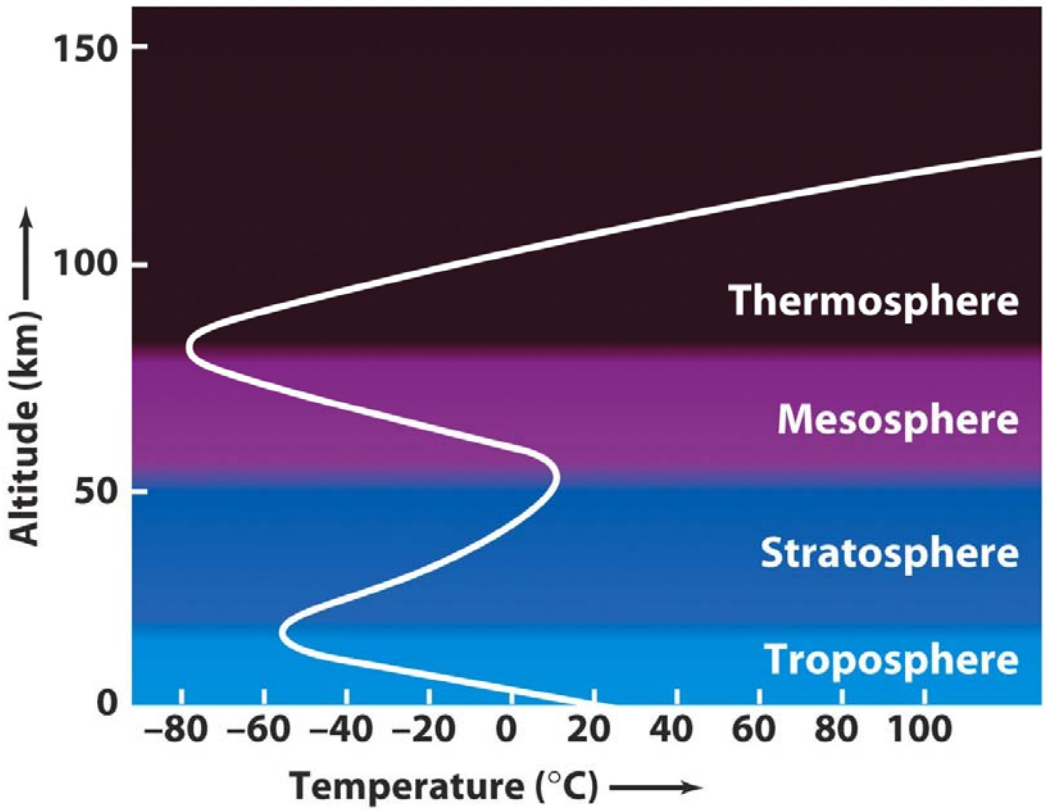
•Over time, O_2 continues to increase, and stablizes at 21%



Earth's Atmosphere: Temperature

- 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: Temperature

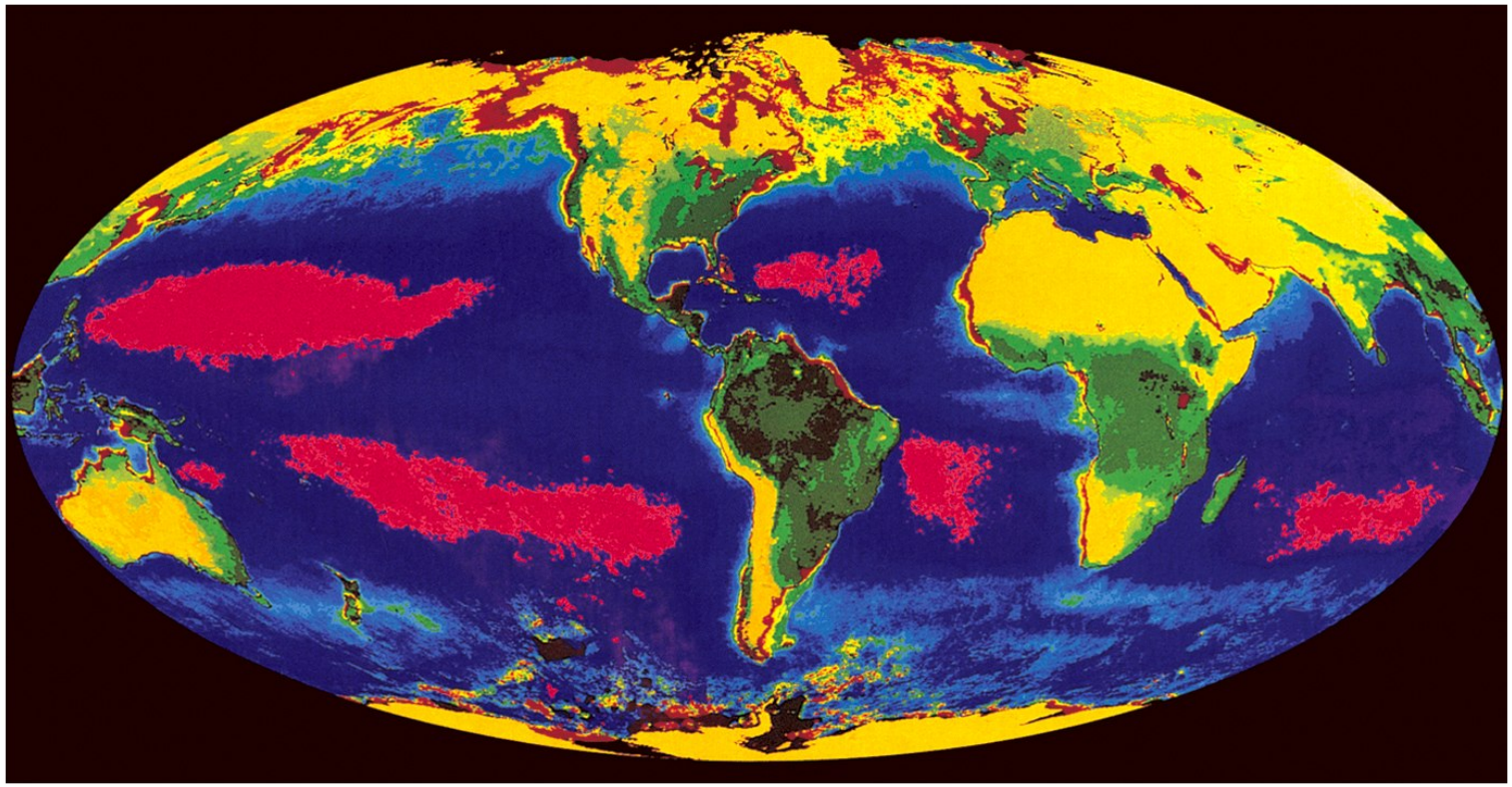
- **Stratosphere:** 12 – 50 km
  - Temperature increases with increasing altitude
  - Temperature increases because an appreciable amount of ozone (O_3) in this layer direct absorb ultraviolet from the Sun
  - This temperature profile does not allow any convection in the stratosphere
- **Mesosphere:** 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

Earth’s Biosphere

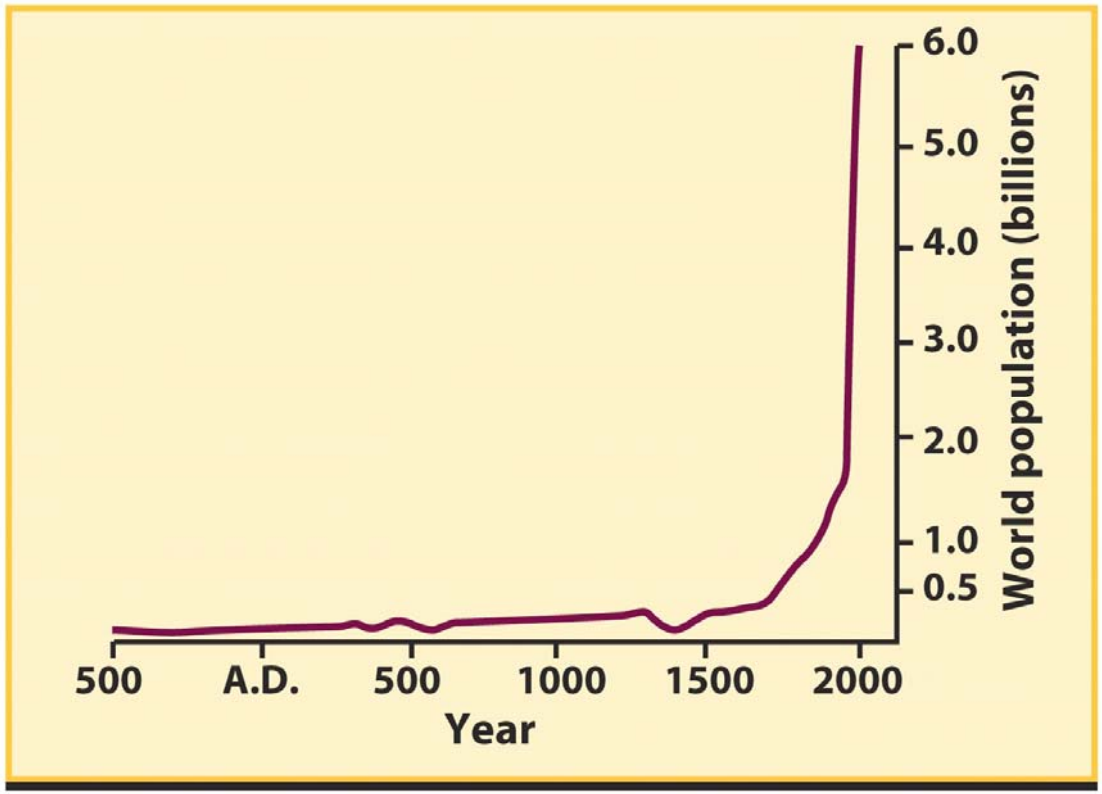
The Distribution of Plant Life



- Land colors designate vegetation: dark green for the rain forests, light green and gold for savannas and farmland, and yellow for the deserts
- Ocean colors show that phytoplankton are most abundant in the red and orange areas and least abundant in the dark blue areas

Earth's Biosphere

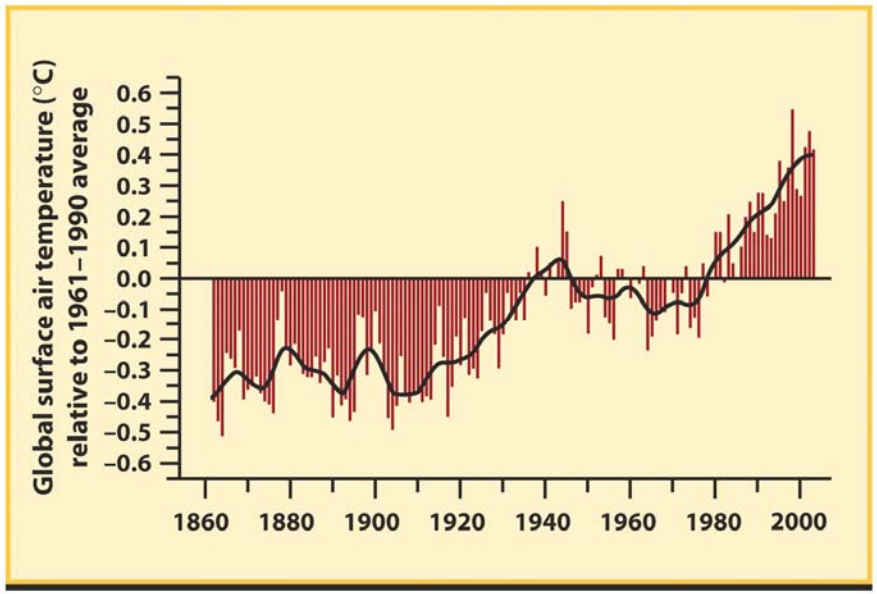
- Human population began to rise in late 1700s with the industrial revolution
- The rise accelerated in the 20th century thanks to medical and technological advances such as antibiotics.

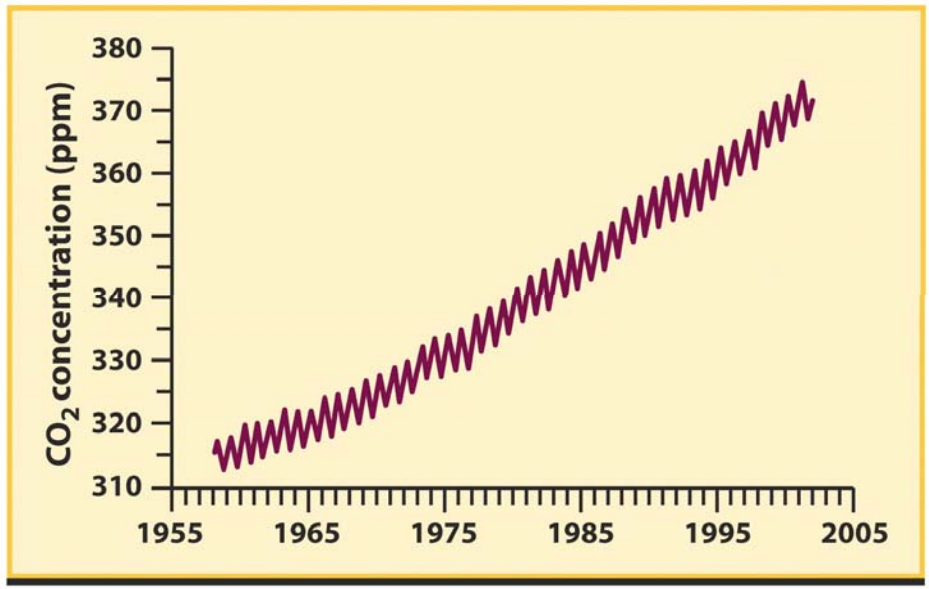


Human Population

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 petroleum and coal

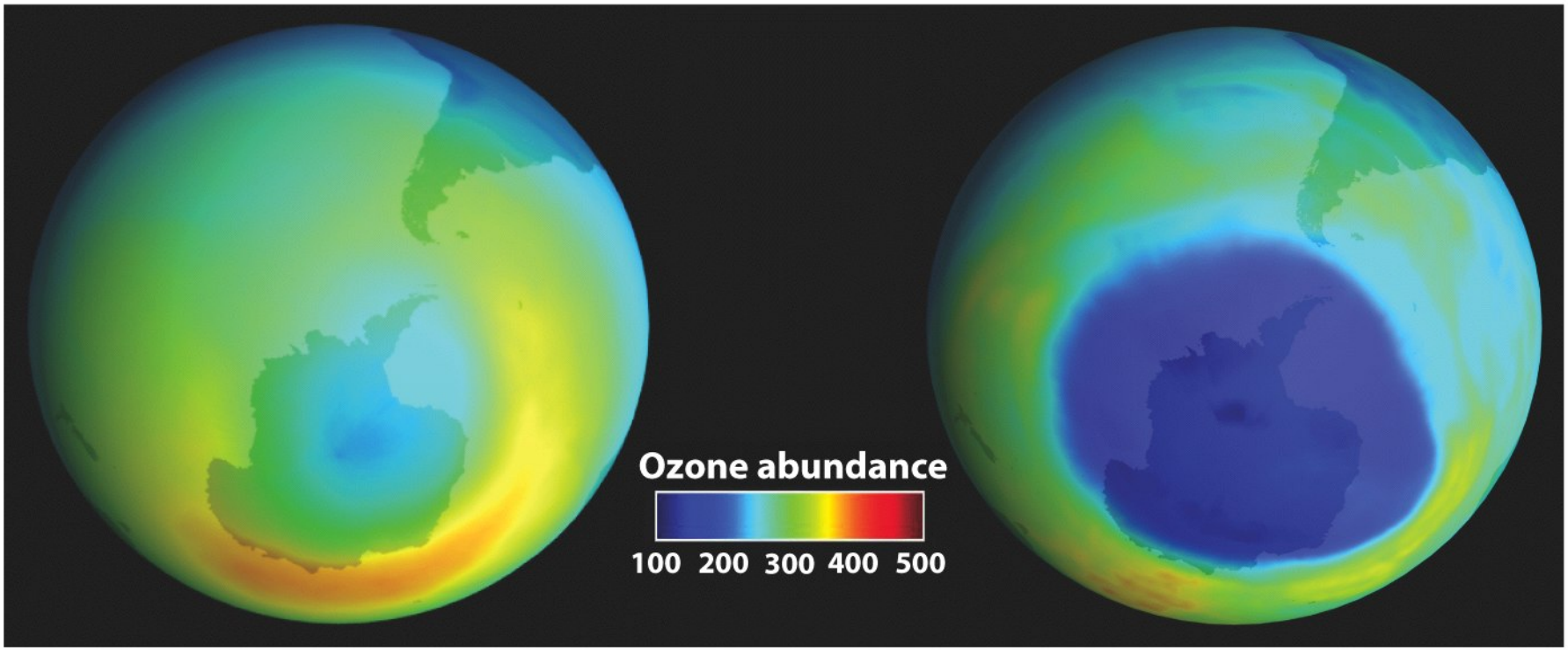




(a) Changes in the Earth’s average temperature

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



October 1979 September 2003

Final Notes on Chap. 9

- 7 sections, all studied.