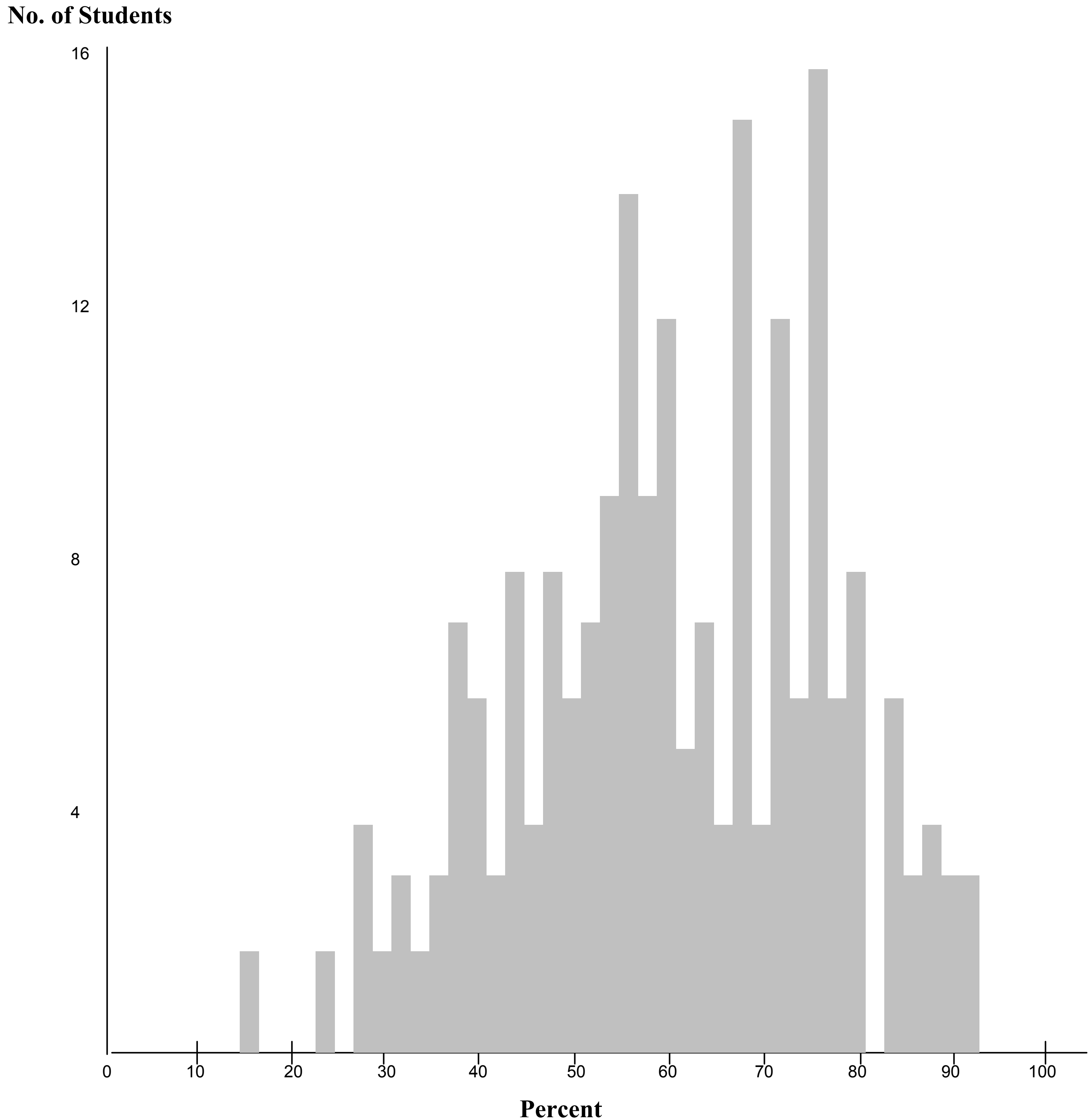
Midterm Exam

- 75 questions
  - High 69, Low 13, Average 46 (62%)
  - Your scores were uploaded to the Mastering Astronomy gradebook yesterday
- Rough breakdown:

– 60-69, A	41-42, C+
– 58-60, A-	34-40, C
– 55-57, B+	26-33, D
– 46-54, B	25-13, F
– 43-45, B-	

A: 32
B: 80
C: 42
D: 18
F: 8

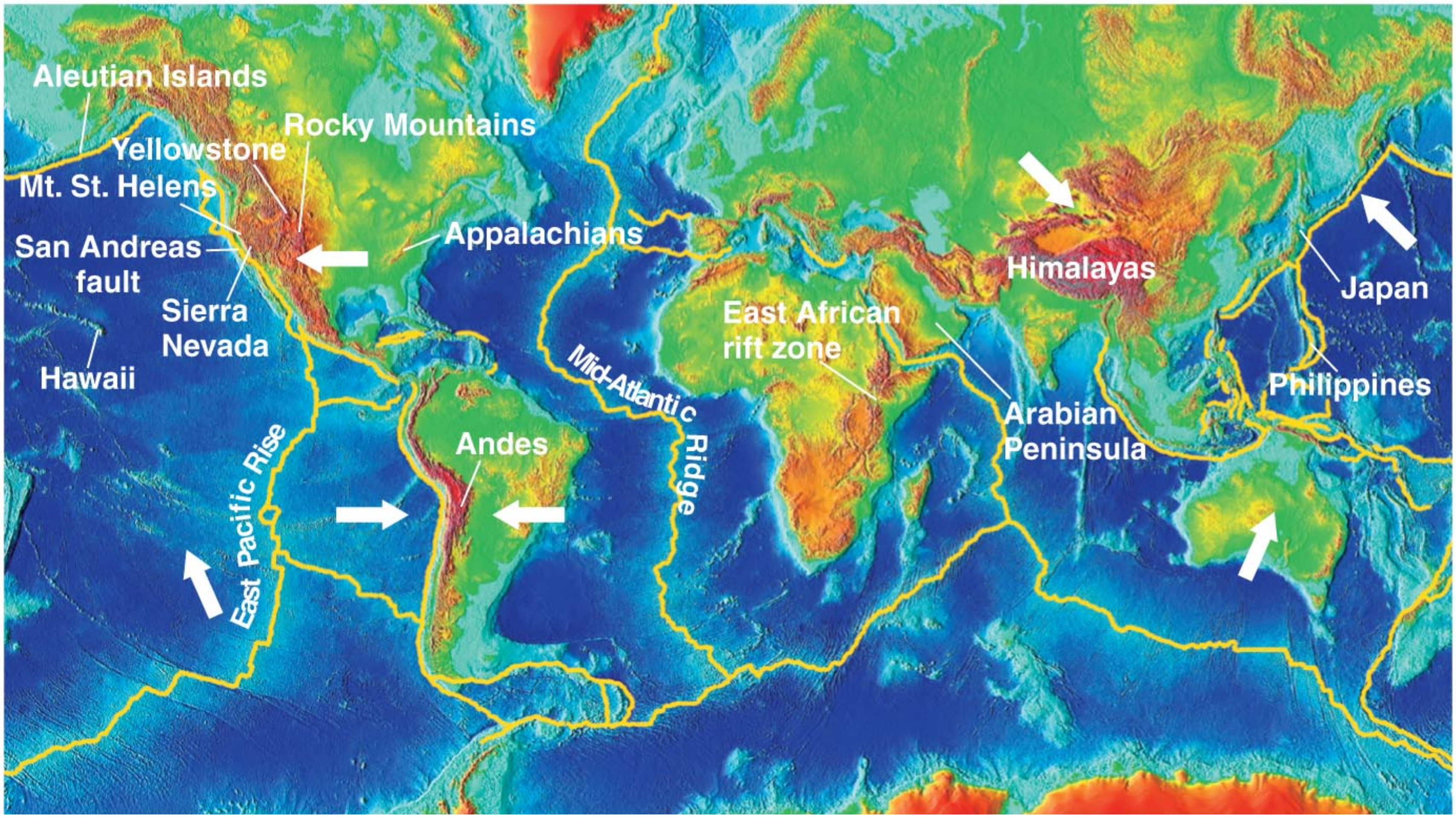


9.6 The Unique Geology of Earth

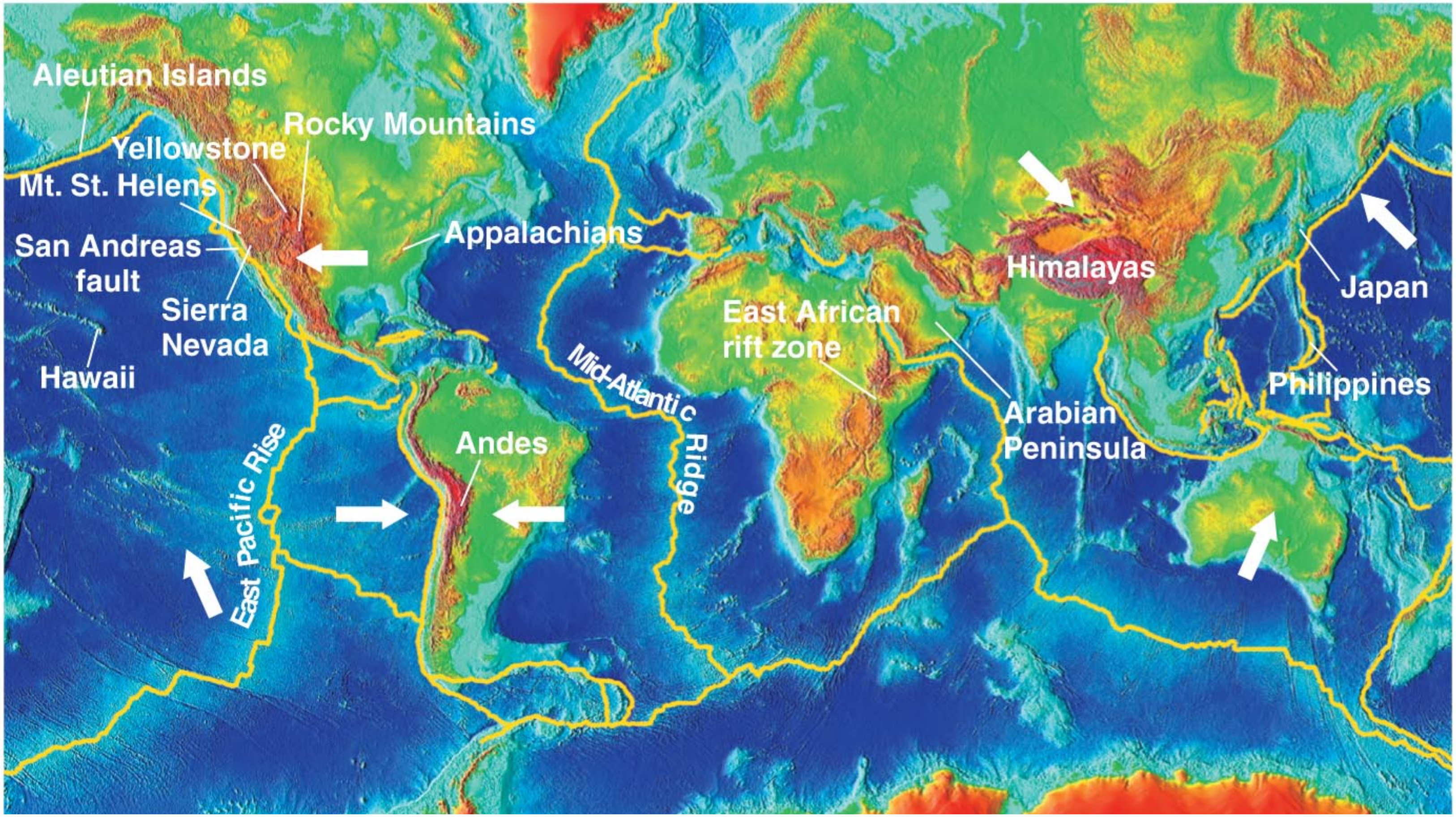
Our goals for learning:

- How do we know Earth's surface is in motion?
- How is Earth's surface shaped by plate tectonics?
- Was Earth's geology destined from birth?

How do we know that Earth's surface is in motion?



Continental Motion



- Motion of the continents can be measured with GPS.

Continental Motion

- The idea of continental drift was inspired by the puzzle-like fit of the continents.
- Mantle material erupts where the seafloor spreads.
- This only started to be understood in the 1960s!

The North Pacific: an Example of Tectonics on a Sphere

by
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R. L. PARKER
Institute of Geophysics and Planetary Physics,
University of California at San Diego

Individual aseismic areas move as rigid plates on the surface of a sphere. Application of the Mercator projection to slip vectors shows that the paving stone theory of world tectonics is correct and applies to about a quarter of the Earth's surface.

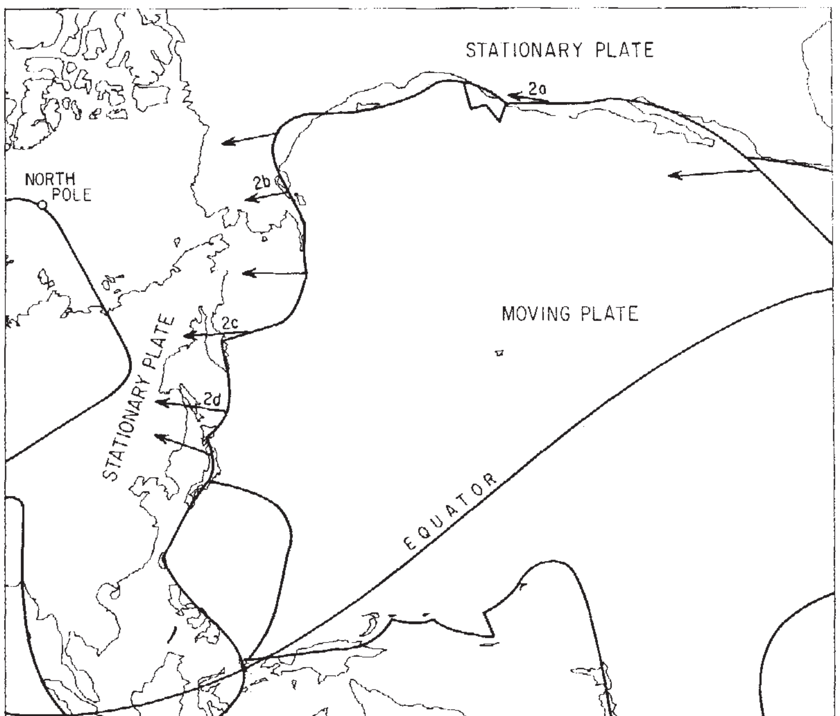


Fig. 3. A Mercator projection of the Pacific with a pole at 50° N., 85° W. The arrows show the direction of motion of the Pacific plate relative to that containing North America and Kamchatka. If both plates are rigid all slip vectors must be parallel with each other and with the upper and lower boundaries of the figure. Possible boundaries of other plates are sketched.

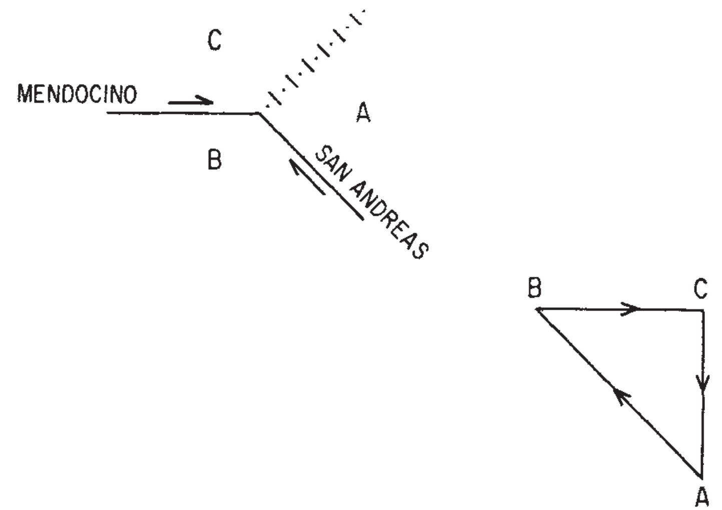
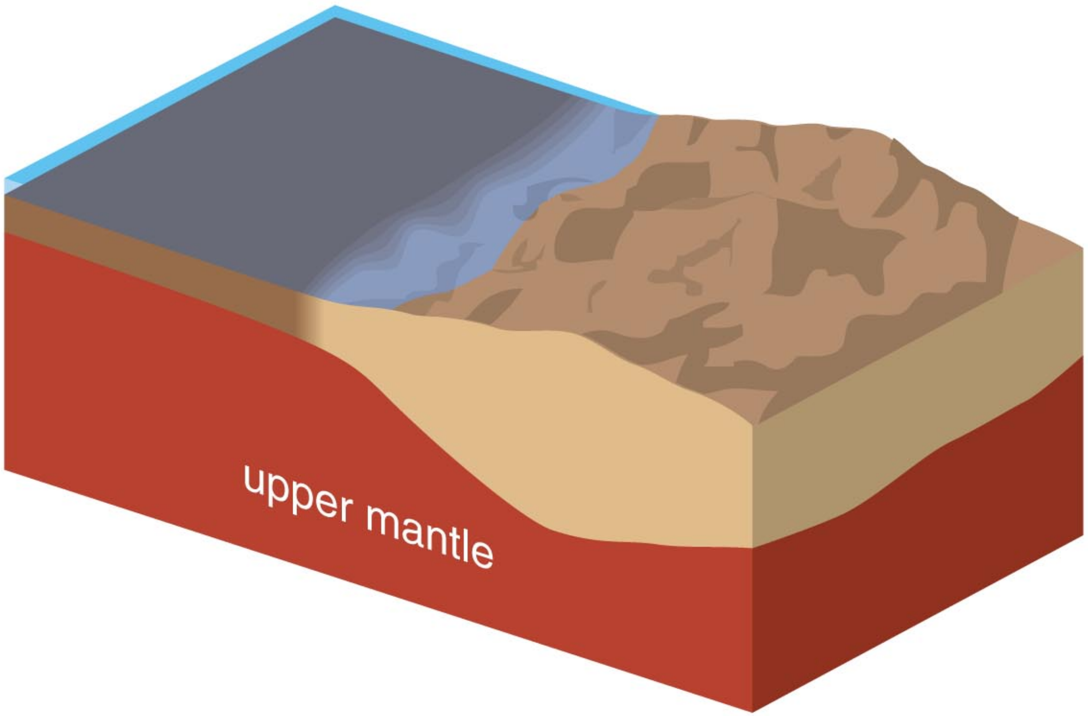


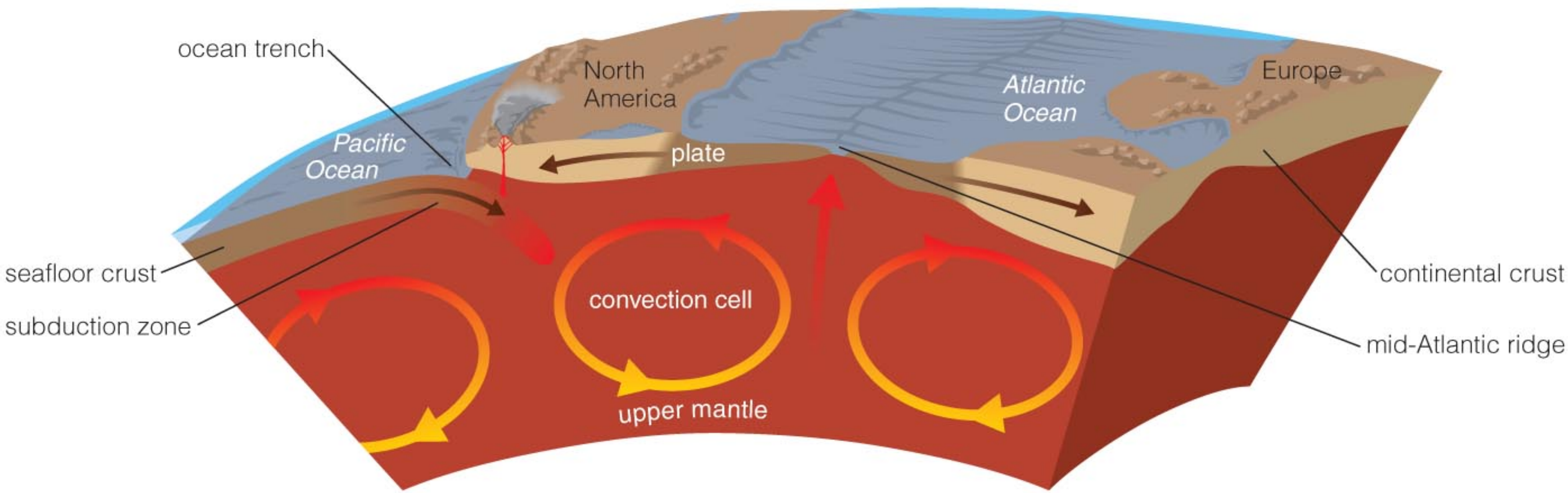
Fig. 5. Both the Mendocino and San Andreas faults can be strike slip if there is a trench to the north or east.

Seafloor Crust

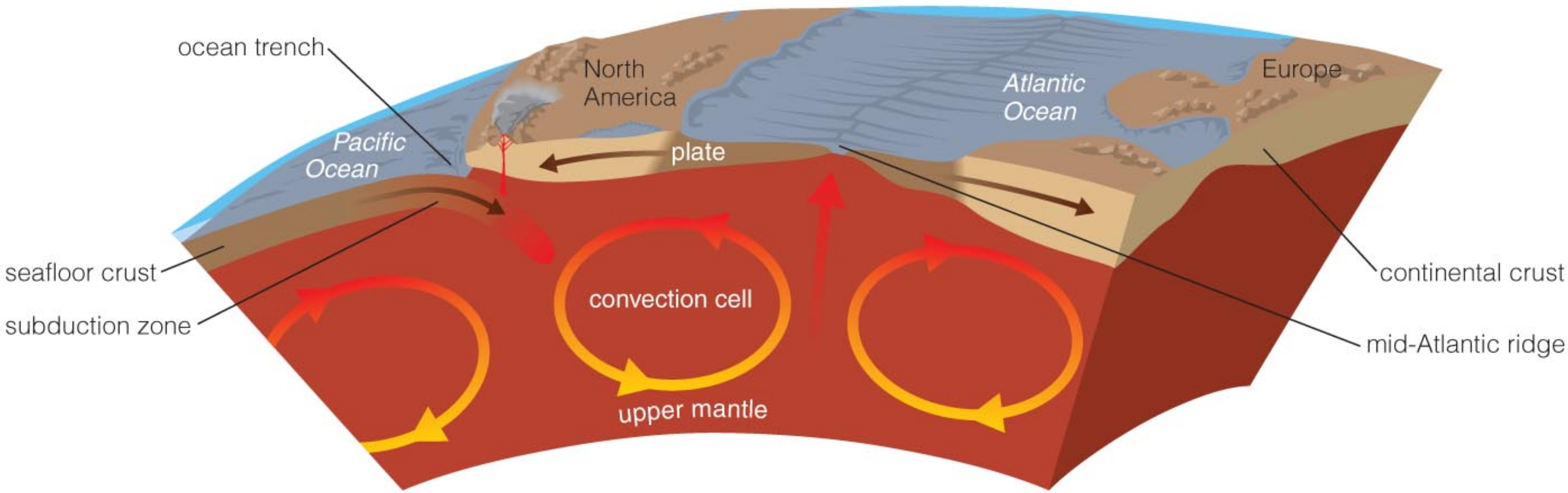


- Thin seafloor crust differs from thick continental crust.
- Dating of the seafloor shows that it is usually quite young.

How is Earth’s surface shaped by plate tectonics?

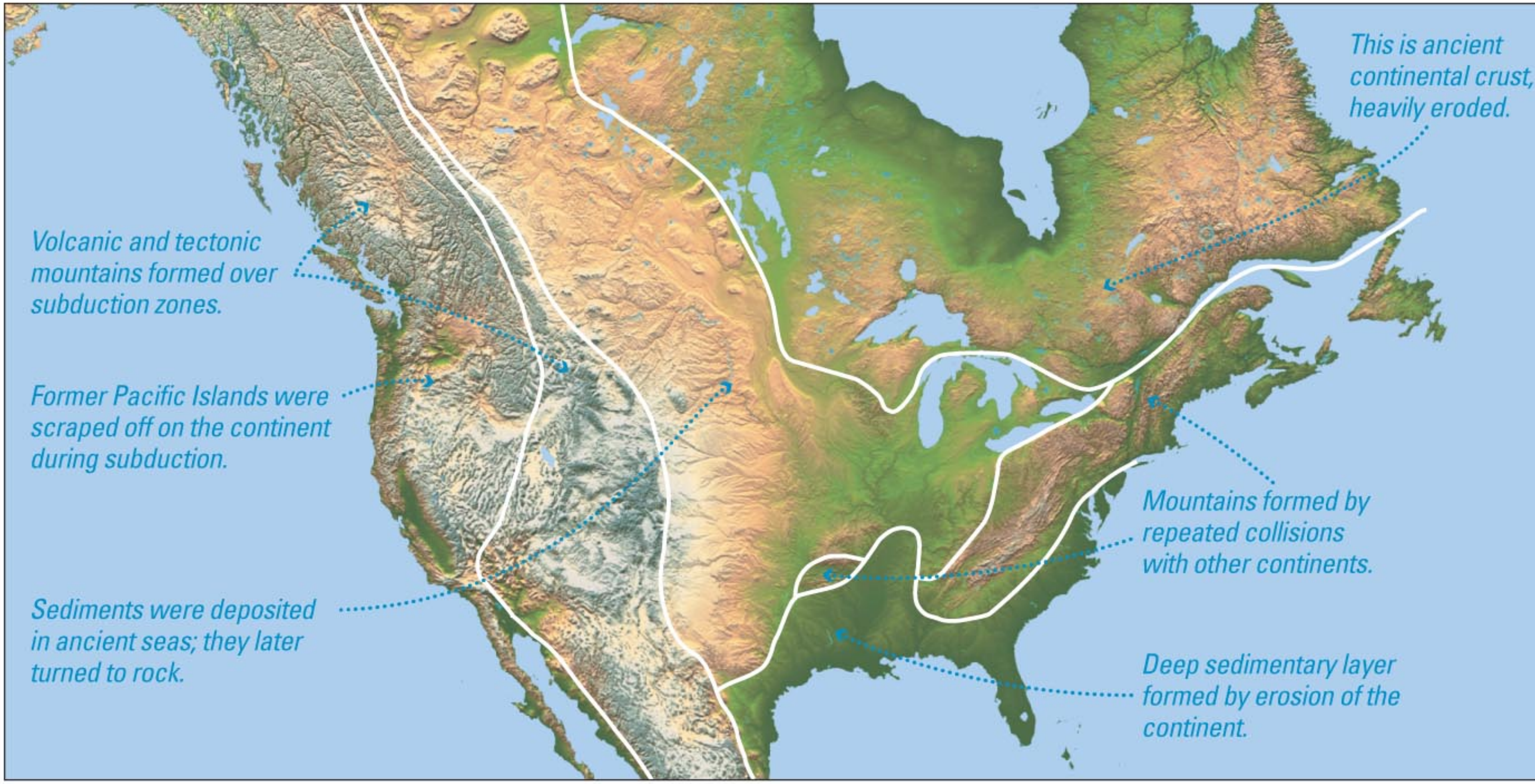


Seafloor Recycling



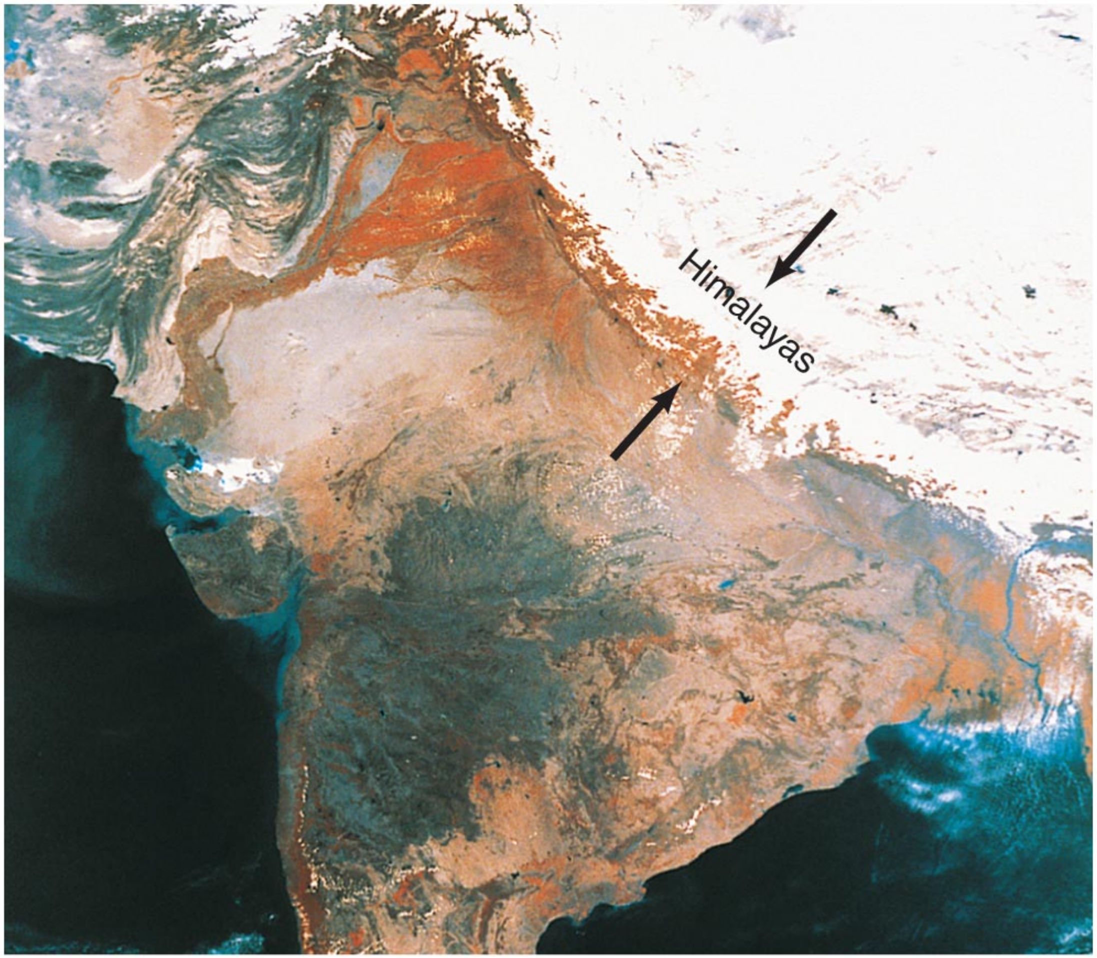
- Seafloor is recycled through a process known as subduction.

Surface Features



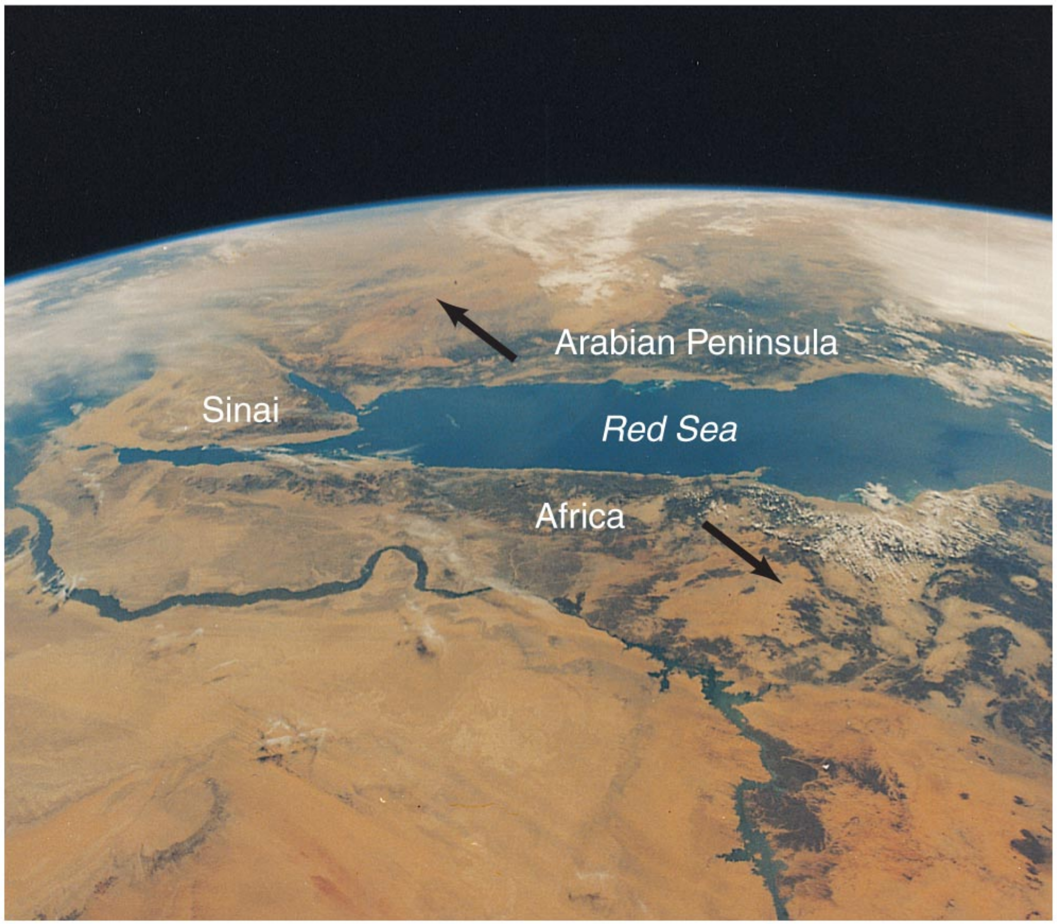
- Major geological features of North America record the history of plate tectonics.

Surface Features



- The Himalayas formed from a collision between plates
- They are still growing

Surface Features



- The Red Sea is formed where plates are pulling apart.

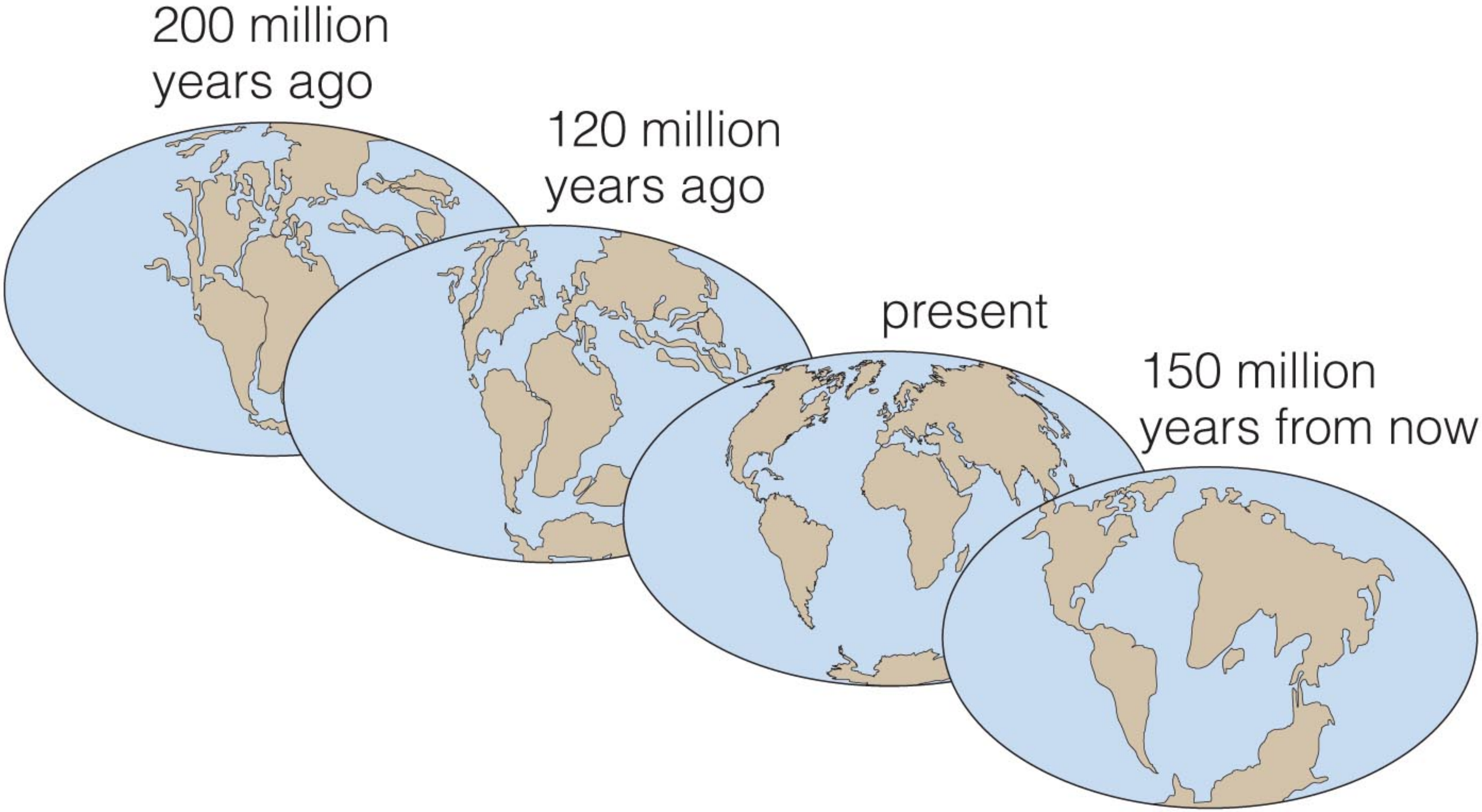
Rifts, Faults, Earthquakes

- The San Andreas fault in California is a plate boundary.
- Motion of plates can cause earthquakes.

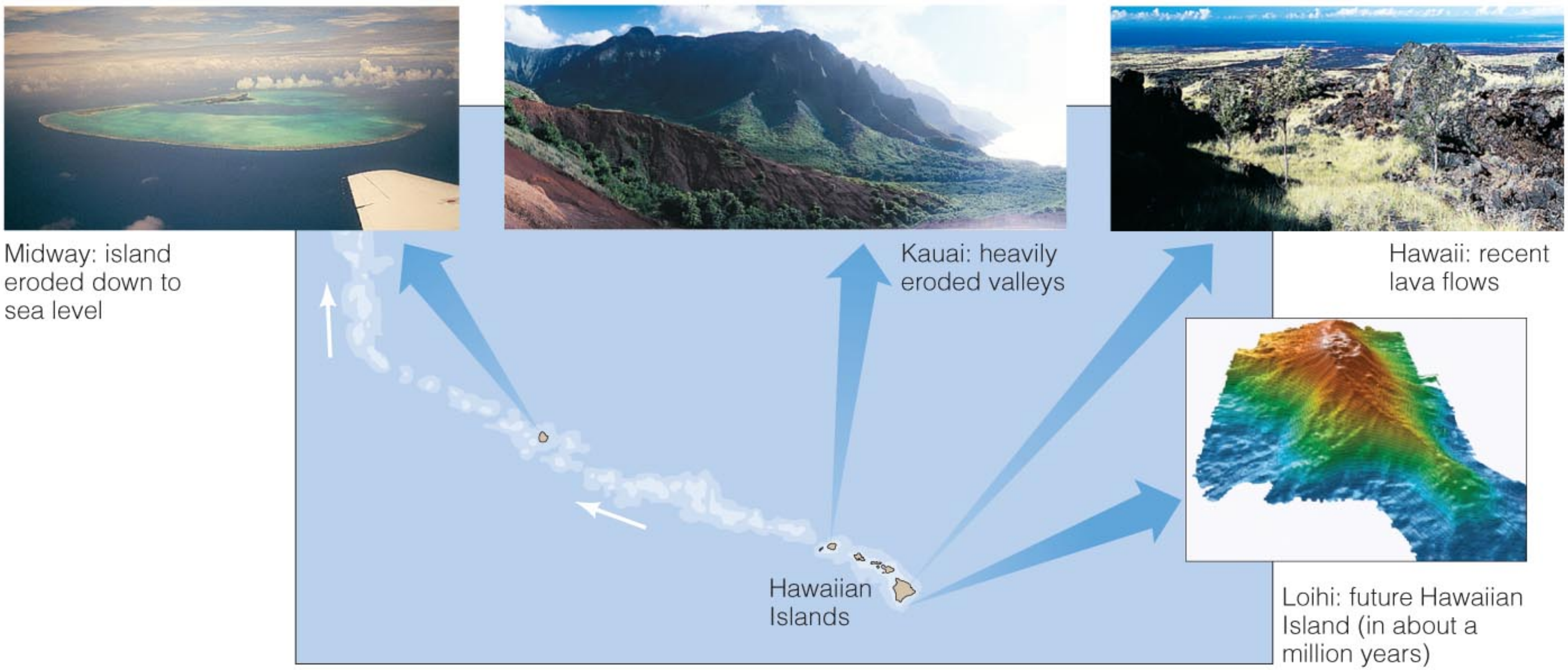
Plate Motions

- Measurements of plate motions tell us past and future layout of the continents.

We can understand the recent past and estimate the future

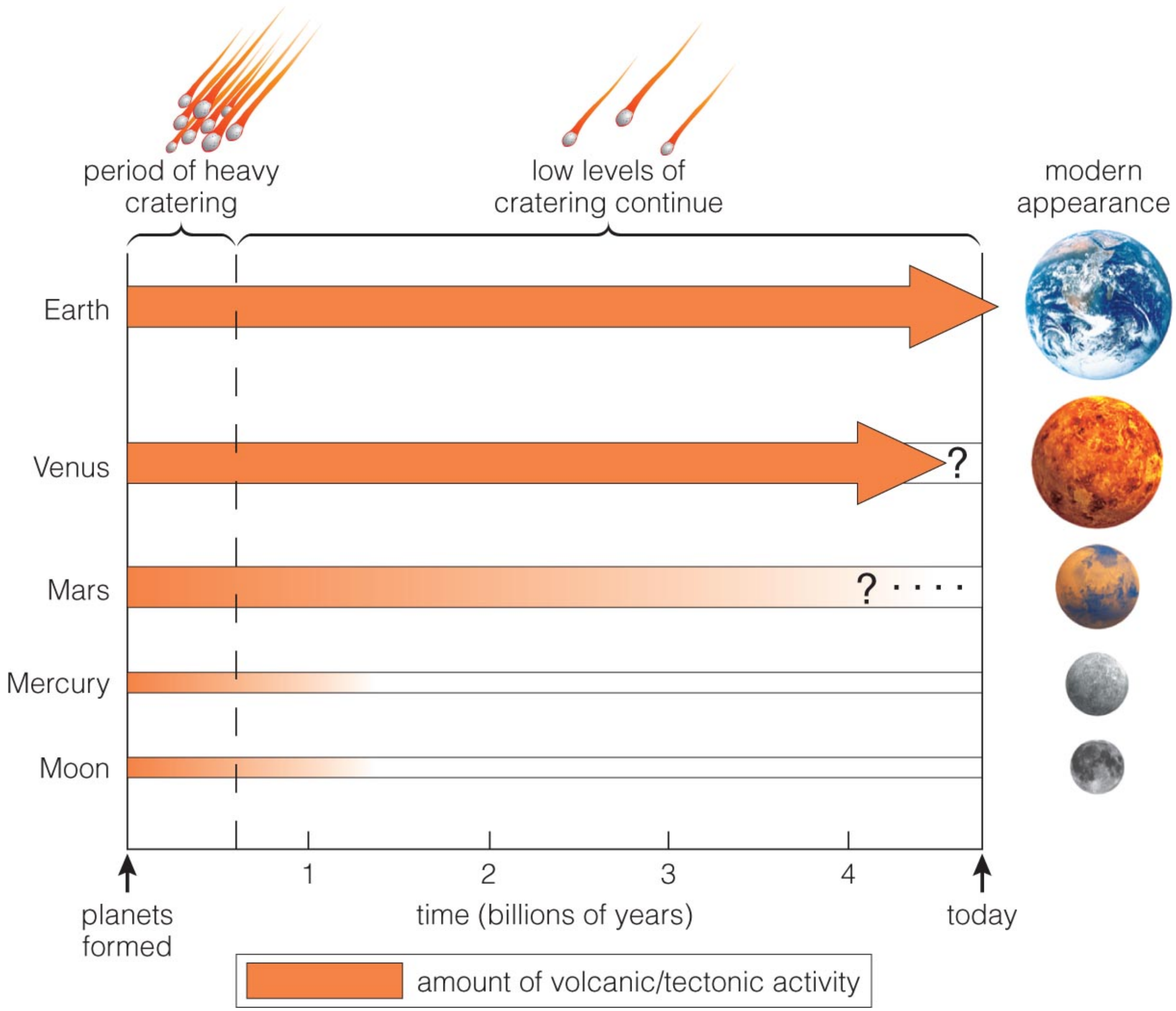


Hot Spots

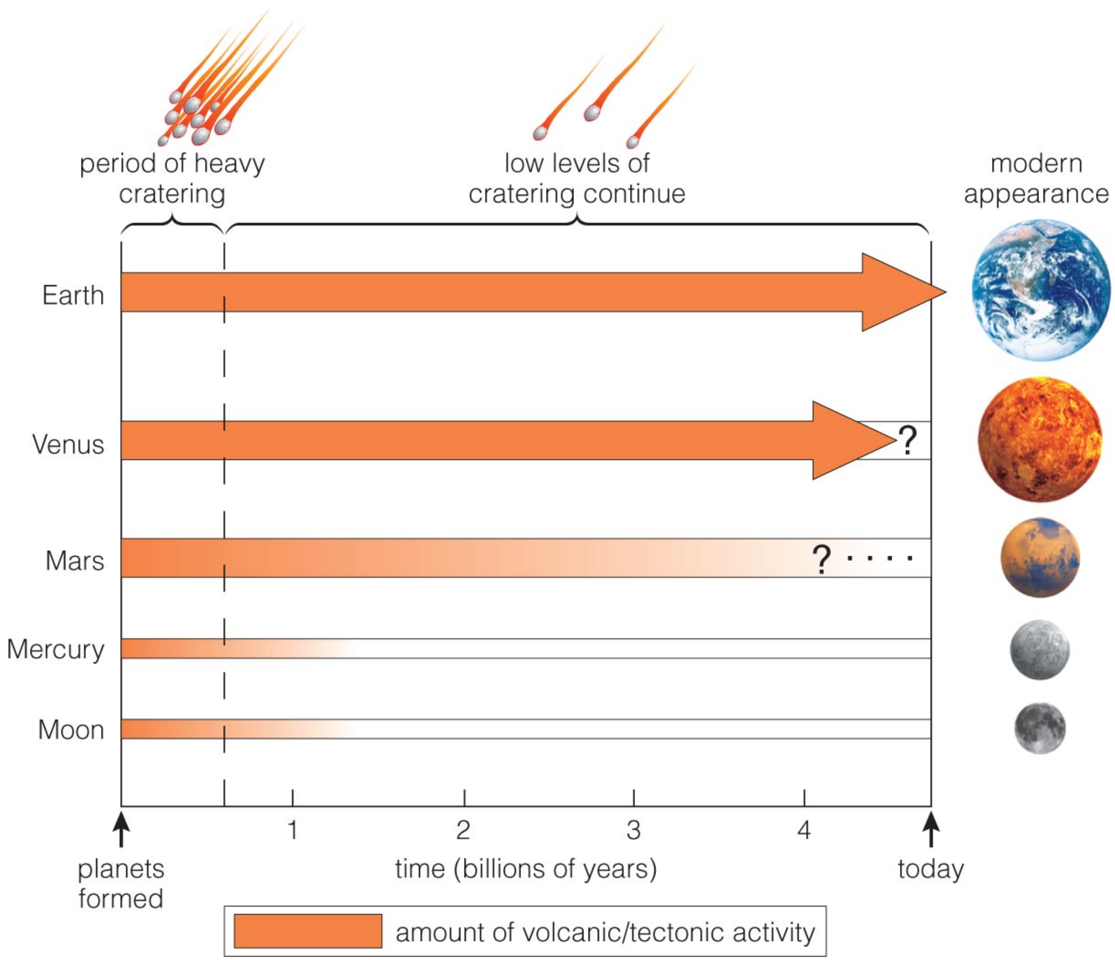


- The Hawaiian islands have formed where a plate is moving over a volcanic hot spot.

Was Earth's geology destined from birth?



Earth's Destiny



- Many of Earth's features are determined by its size, rotation, and distance from Sun.
- The reason for plate tectonics is not yet clear.

What have we learned?

- How do we know that Earth's surface is in motion?
  - Measurements of plate motions confirm the idea of continental drift.
- How is Earth's surface shaped by plate tectonics?
  - Plate tectonics is responsible for subduction, seafloor spreading, mountains, rifts, and earthquakes.

What have we learned?

- Was Earth's geology destined from birth?
  - Many of Earth's features are determined by its size, distance from Sun, and rotation rate.
  - The reason for plate tectonics is still a mystery.

INEVITABILITY OF PLATE TECTONICS ON SUPER-EARTHS

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Received 2007 July 20; accepted 2007 September 28; published 2007 October 22

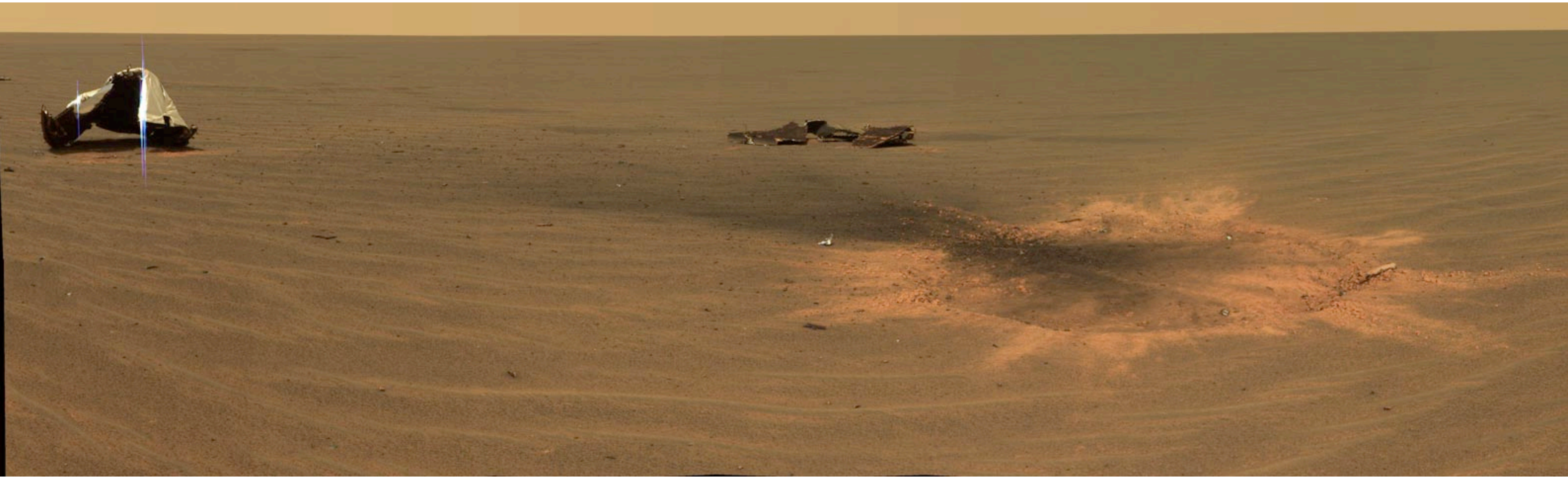
Plate Tectonics on Super Earths?

Geological consequences of super-sized Earths

C. O'Neill[1] and A. Lenardic[2]

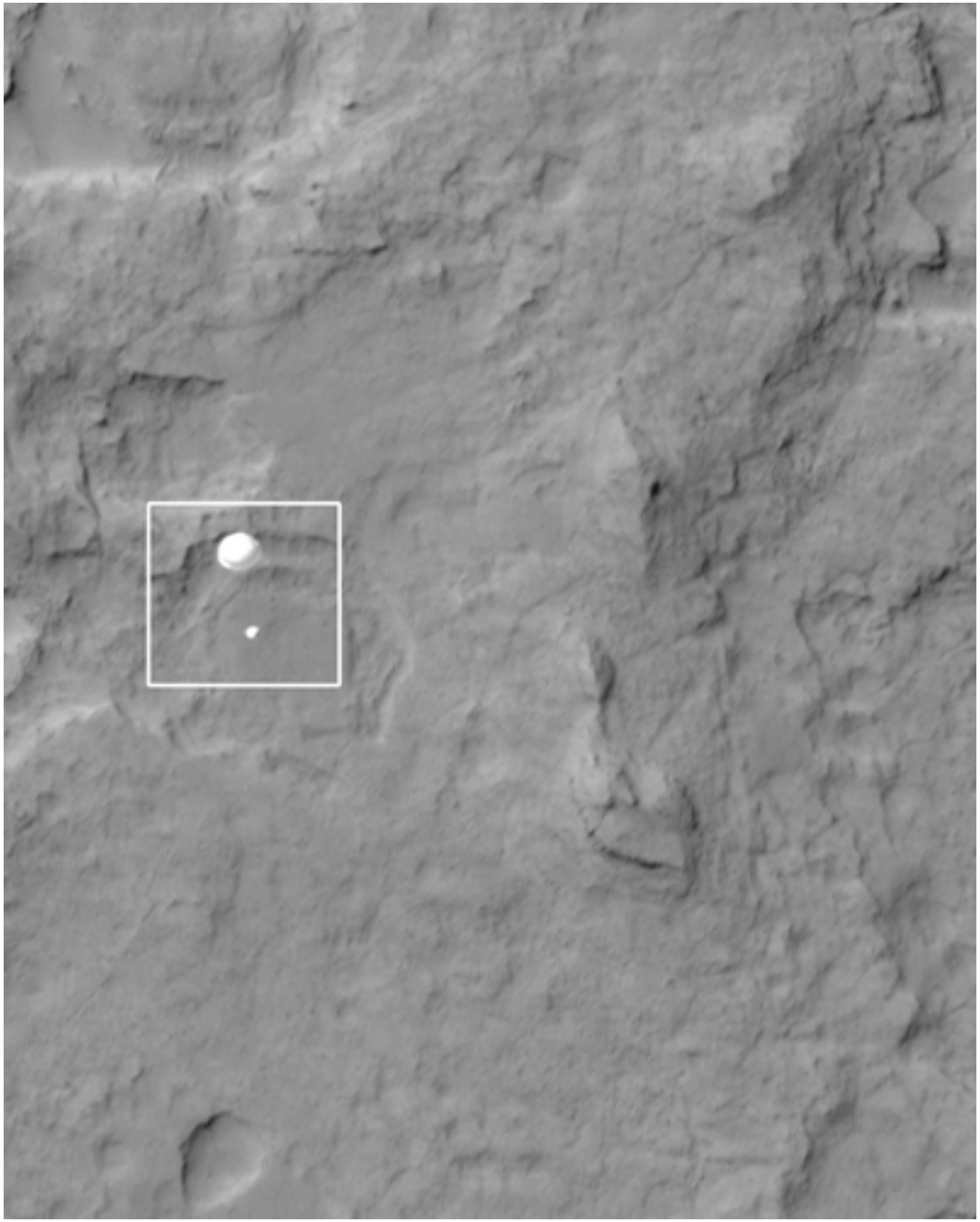
Received 6 May 2007; revised 20 July 2007; accepted 22 August 2007; published 11 Oc

My favorite image of Mars



2005, Opportunity rover heat shield

2011 Mars Curiosity Rover descent, as seen from Mars Reconnaissance Orbiter



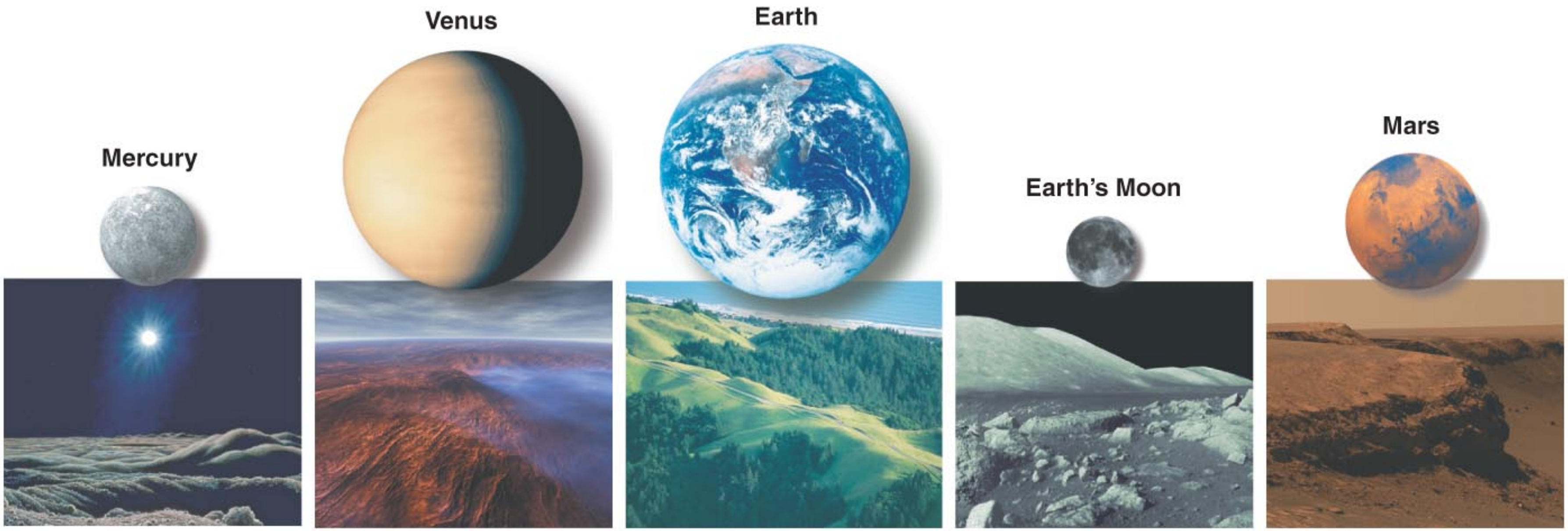
Chapter 10
Planetary Atmospheres:
Earth and the Other Terrestrial Worlds

10.1 Atmospheric Basics

Our goals for learning:

- What is an atmosphere?
- How does the greenhouse effect warm a planet?
- Why do atmospheric properties vary with altitude?

What is an atmosphere?

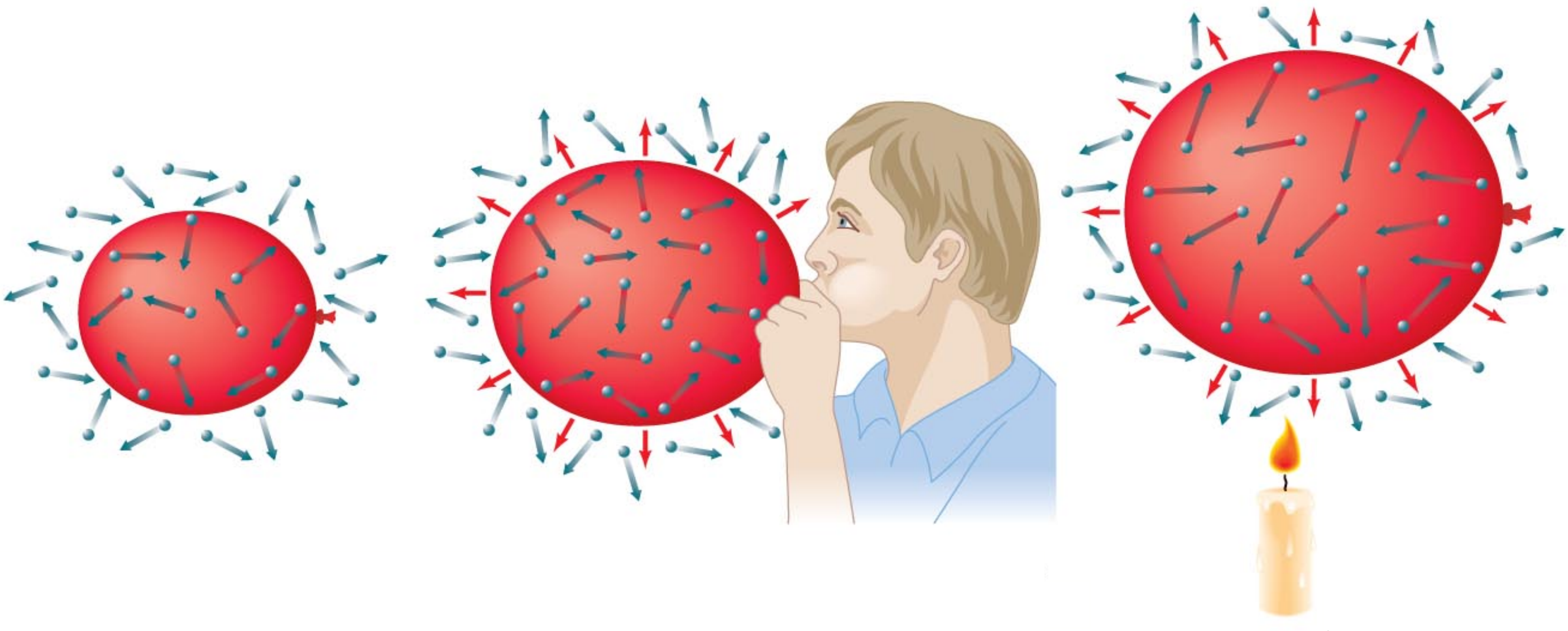


An atmosphere is a (usually very thin) layer of gas that surrounds a world.

Earth's Atmosphere

- About 10 kilometers thick
- Consists mostly of molecular nitrogen (N_2) and oxygen (O_2).
- Thickness of a dollar bill on a 12" globe

Atmospheric Pressure

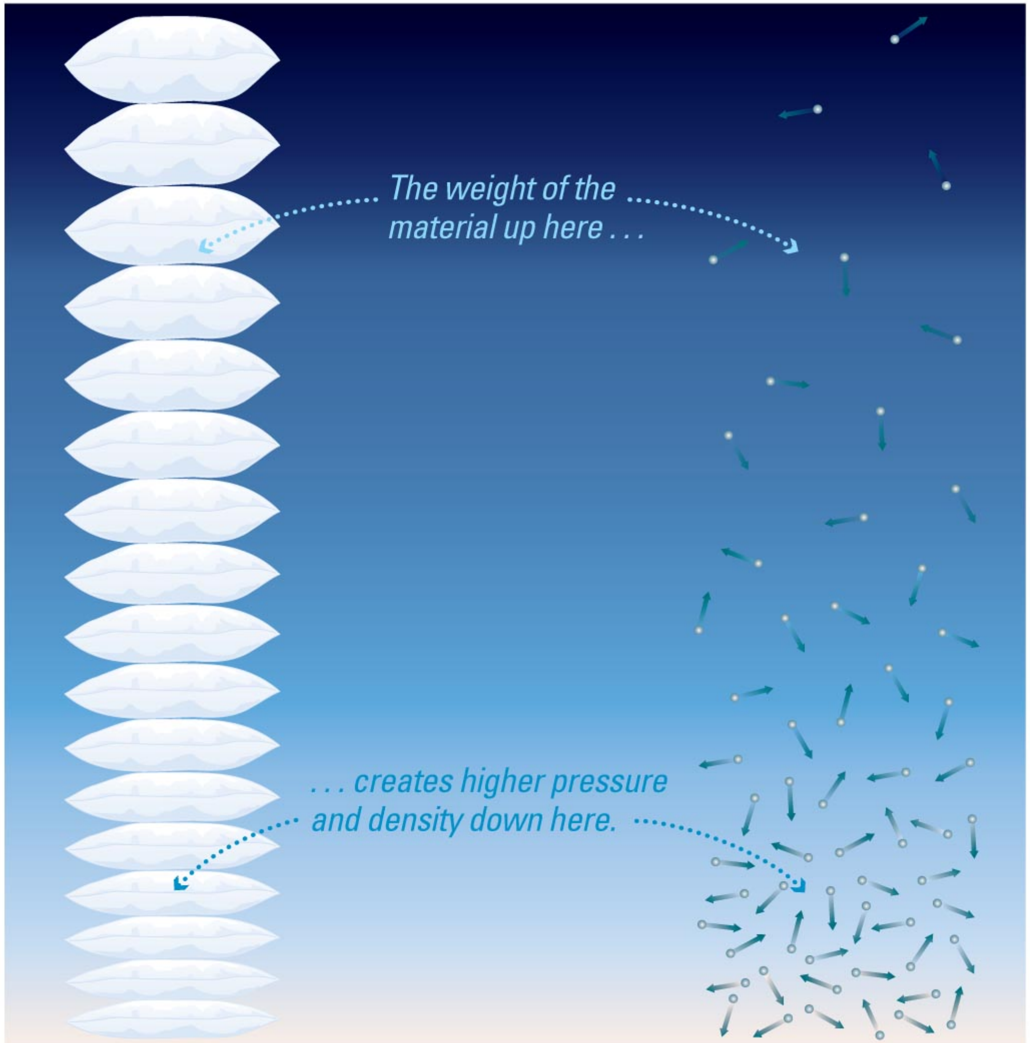


Gas pressure depends on both density and temperature.

Adding air molecules increases the pressure in a balloon.

Heating the air also increases the pressure—molecules move faster

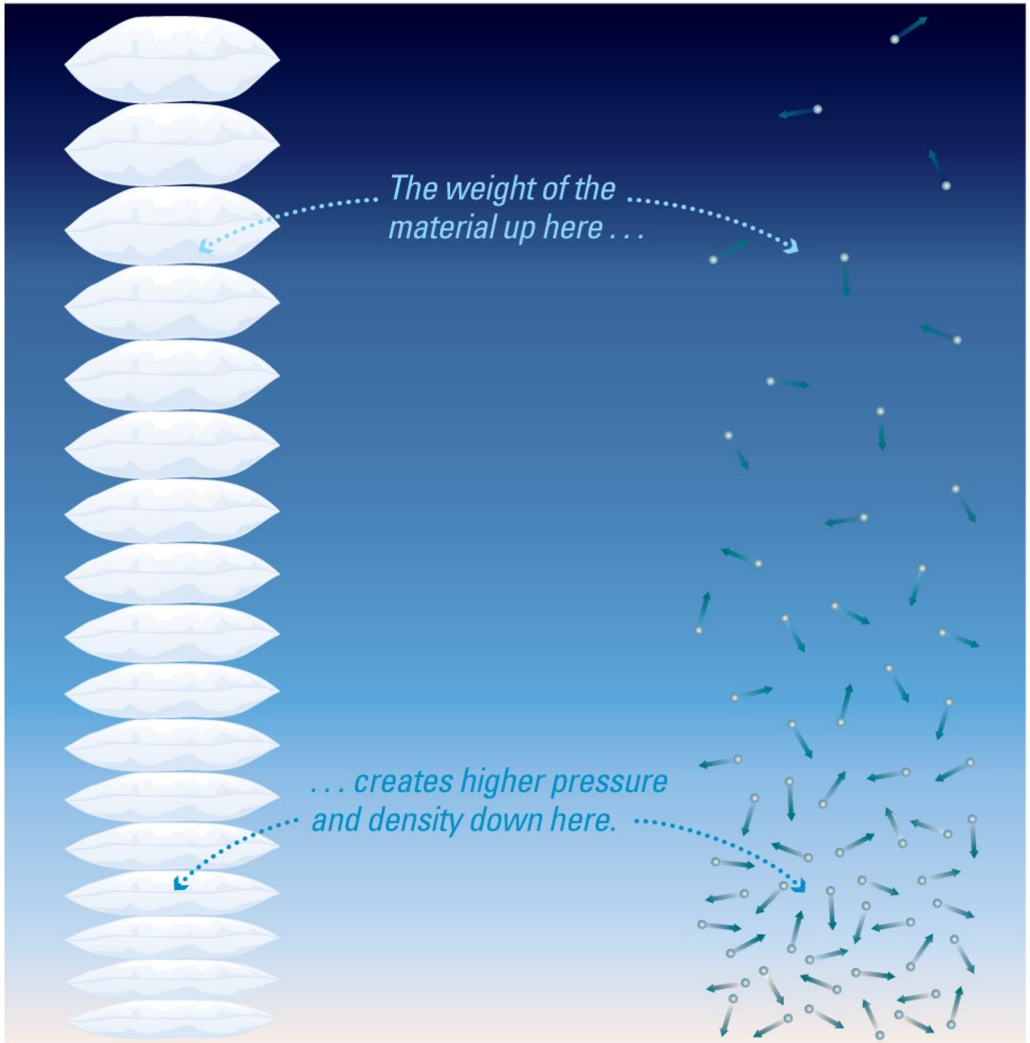
Atmospheric Pressure



- Pressure and density decrease with altitude because the weight of overlying layers is less.

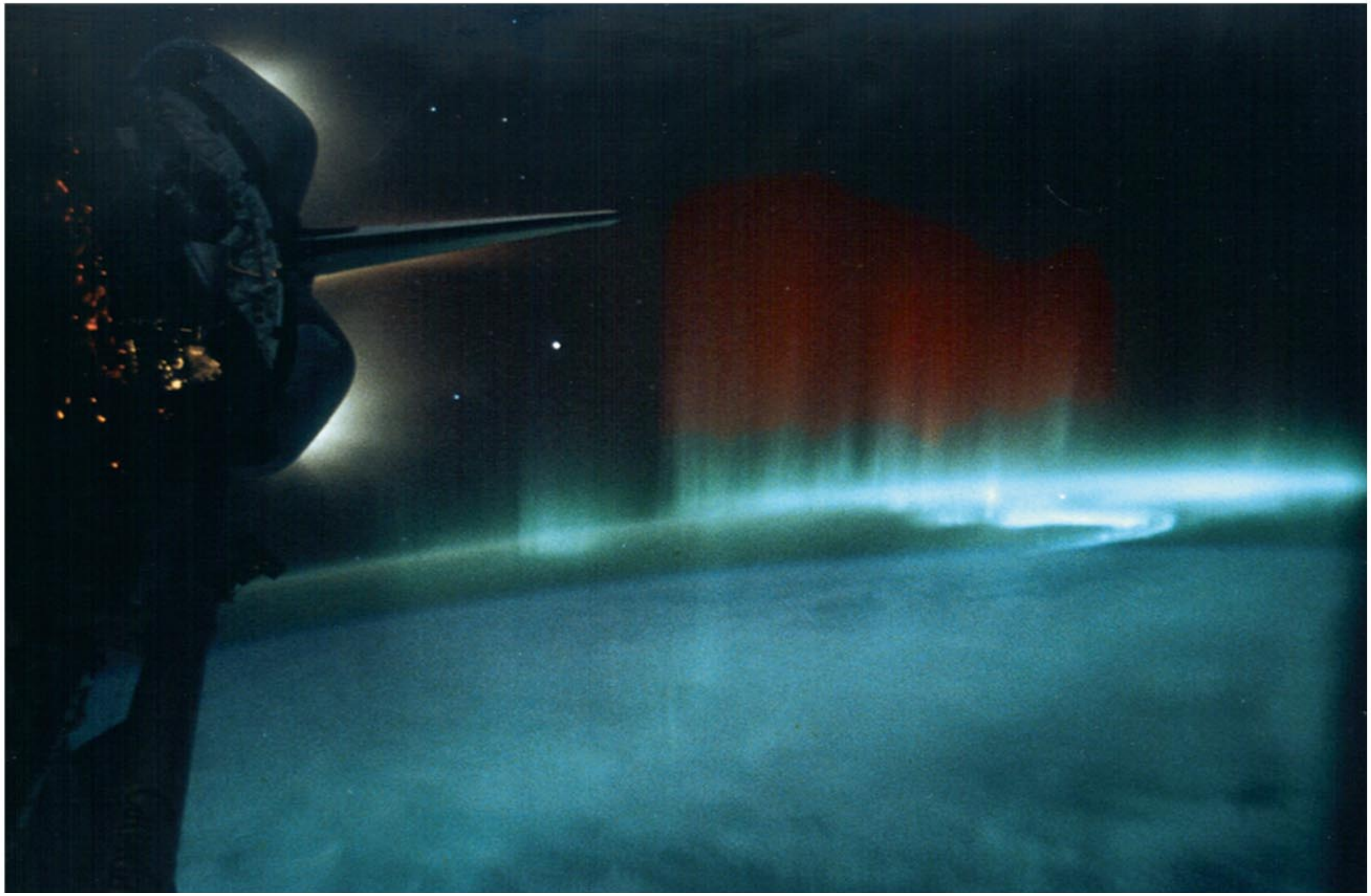
- Earth's pressure at sea level is:
  - 1.03 kg per sq. meter
  - 14.7 lb per sq. inch
  - 1 bar

Where does an atmosphere end?



- There is no clear upper boundary.
- Most of Earth's gas is less than 10 kilometers from surface, but a small fraction extends to more than 100 kilometers.
- Altitudes more than 60 kilometers are considered "space." (Sky is black)

Where does an atmosphere end?

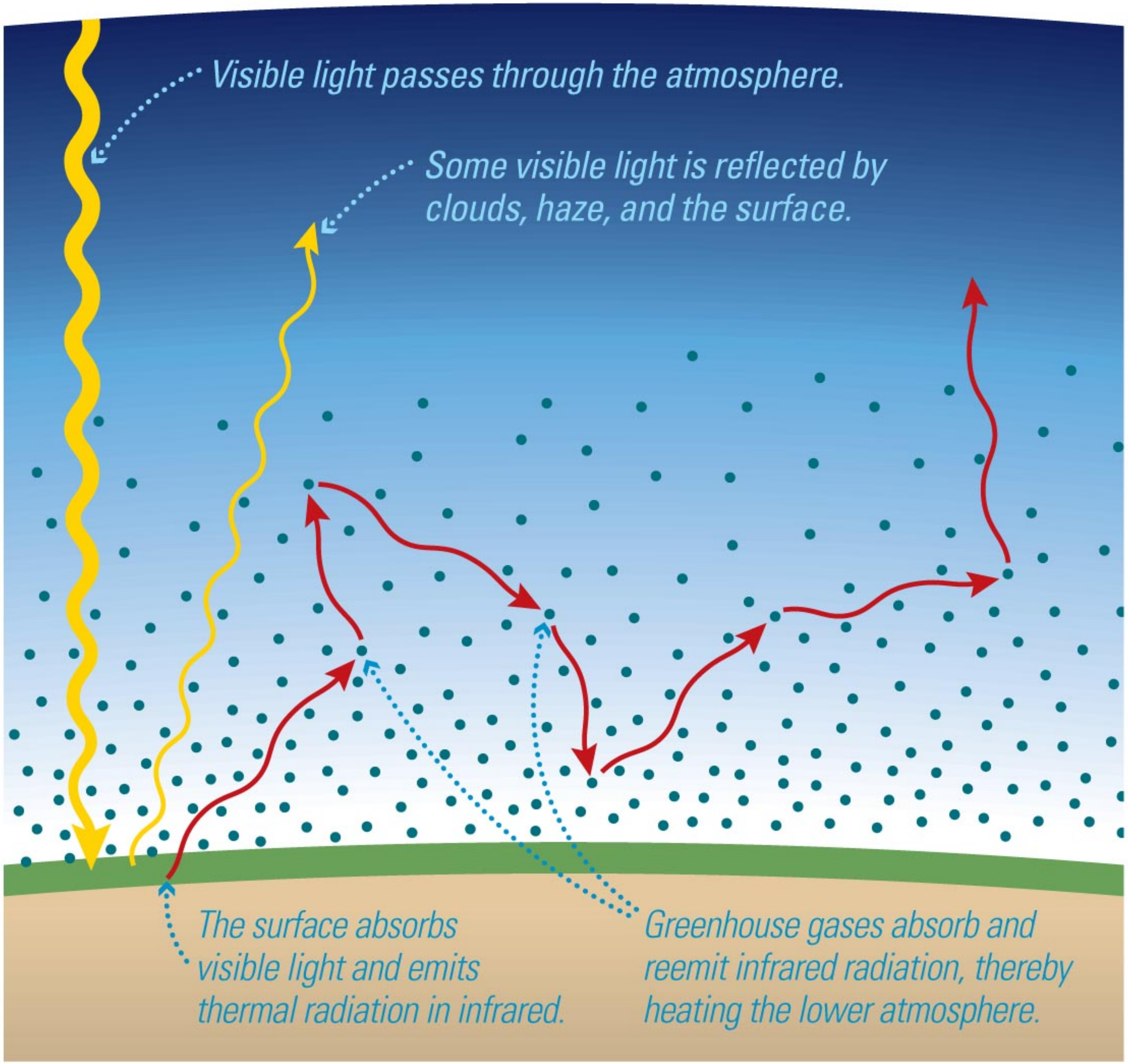


- Small amounts of gas are present even above 300 kilometers.

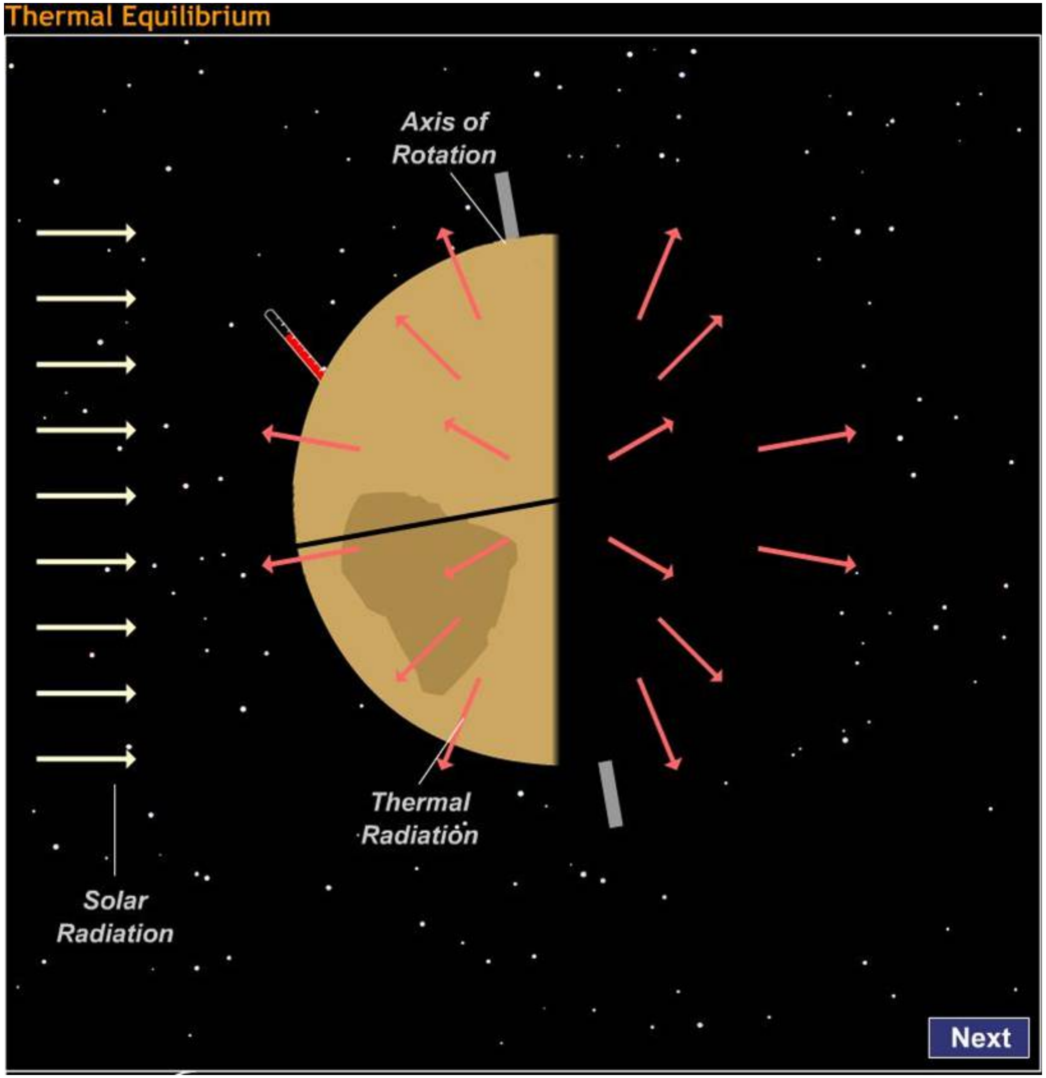
Effects of Atmospheres

- They create pressure that determines whether liquid water can exist on surface.
- They absorb and scatter light.
- They create wind, weather, and climate.
- They interact with the solar wind to create a magnetosphere.
- They can make planetary surfaces warmer through the greenhouse effect.

How does the greenhouse effect warm a planet?



Planetary Temperature



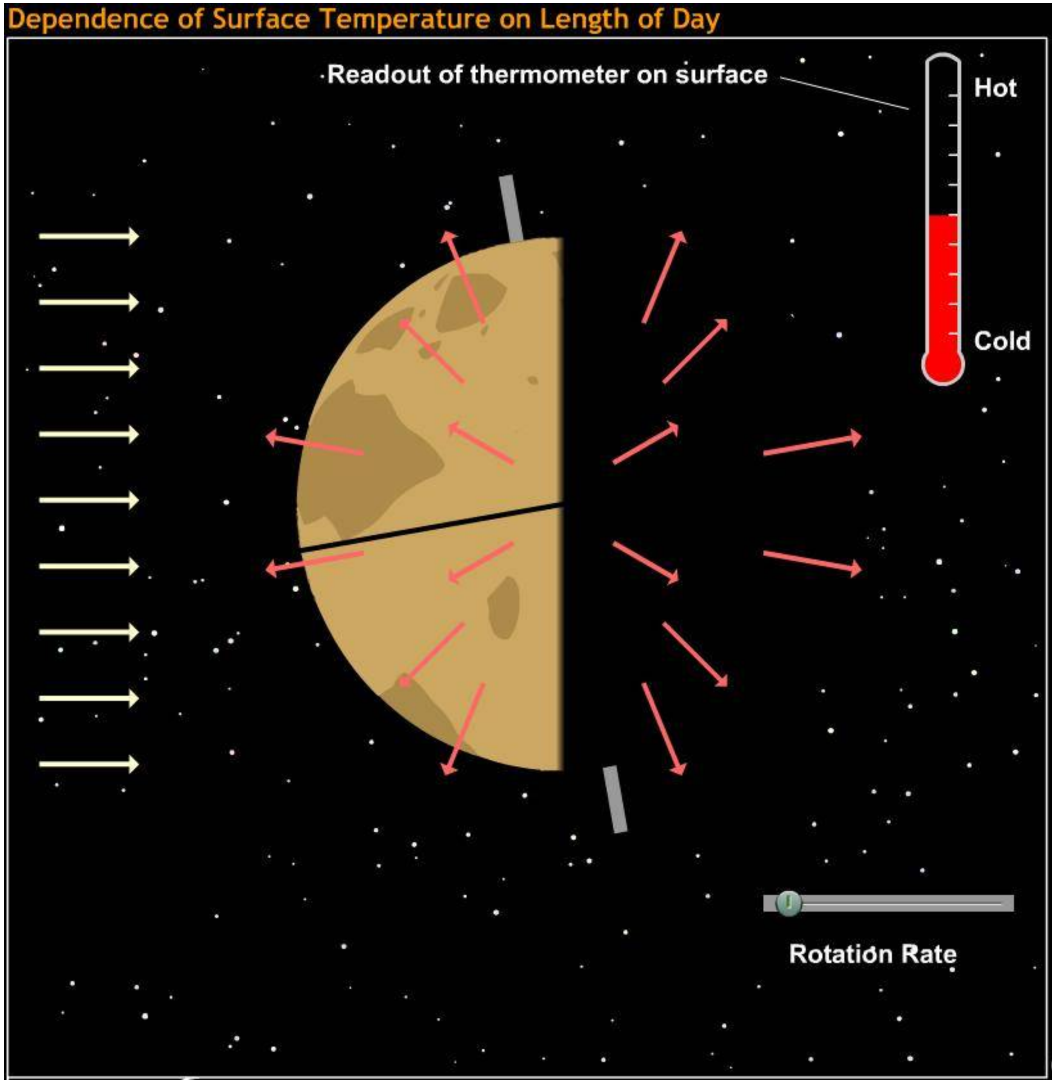
- A planet’s surface temperature is determined by the balance between energy from sunlight it absorbs and energy of outgoing thermal radiation.

Temperature and Distance

- A planet's distance from the Sun determines the total amount of incoming sunlight.
- In the *absence of an atmosphere* we can calculate the mean surface temperature of a planet.

$$T = \underline{280\ K} \times [(1\text{-reflectivity})/d^2]^{1/4}$$

Temperature and Rotation



- A planet's rotation rate affects the temperature differences between day and night.
- Faster rotation leads to better day/night homogenization

Temperature and Reflectivity

- A planet's reflectivity (or *albedo*) is the fraction of incoming sunlight it reflects.
- Planets with low albedo absorb more sunlight, leading to hotter temperatures
- Rocks tend to be dark, clouds layers tend to be bright, ices tend to be very bright

"No Greenhouse" Temperatures

TABLE 10.2 The Greenhouse Effect on the Terrestrial Worlds

World	Average Distance from Sun (AU)	Reflectivity	"No Greenhouse" Average Surface Temperature*	Actual Average Surface Temperature	Greenhouse Warming (actual temperature minus "no greenhouse" temperature)
Mercury	0.387	12%	163°C	day: 425°C; night: −175°C	—
Venus	0.723	75%	−40°C	470°C	510°C
Earth	1.00	29%	−16°C	15°C	31°C
Moon	1.00	12%	−2°C	day: 125°C; night: −175°C	—
Mars	1.524	16%	−56°C	−50°C	6°C

*The "no greenhouse" temperature is calculated by assuming no change to the atmosphere other than lack of greenhouse warming. For example, Venus has a lower "no greenhouse" temperature than Earth even though it is closer to the Sun, because the high reflectivity of its bright clouds means that it absorbs less sunlight than Earth.

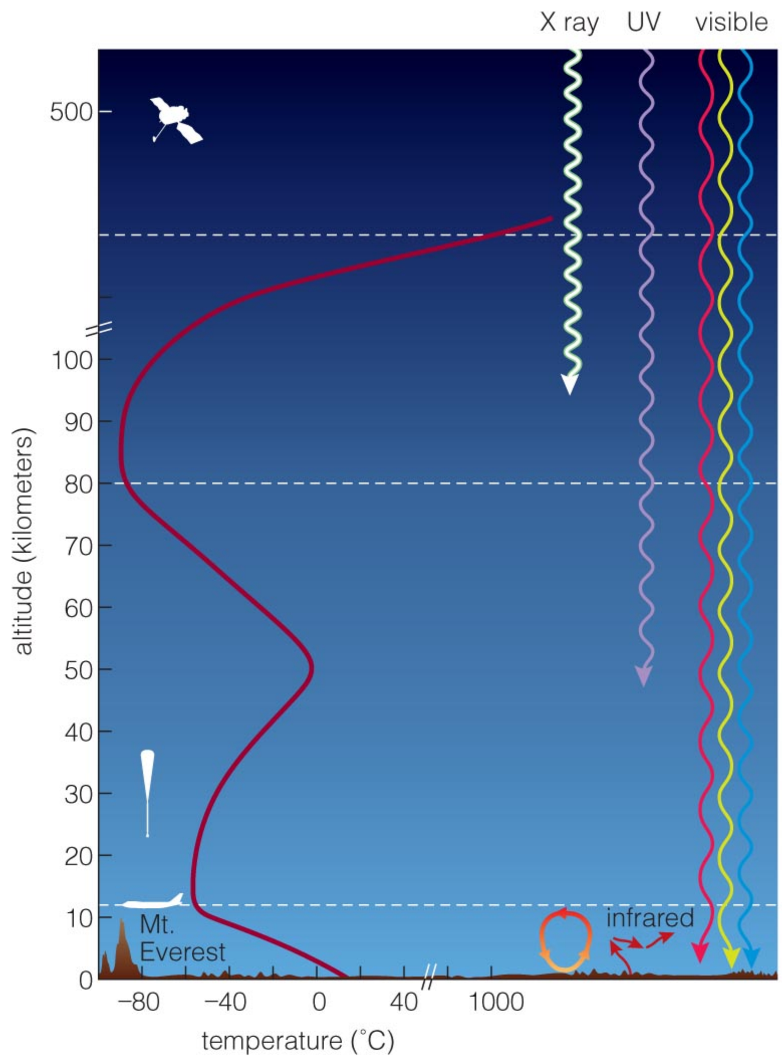
- Venus would be 510°C colder without greenhouse effect.
- Earth would be 31°C colder (below freezing on average).

Thought Question

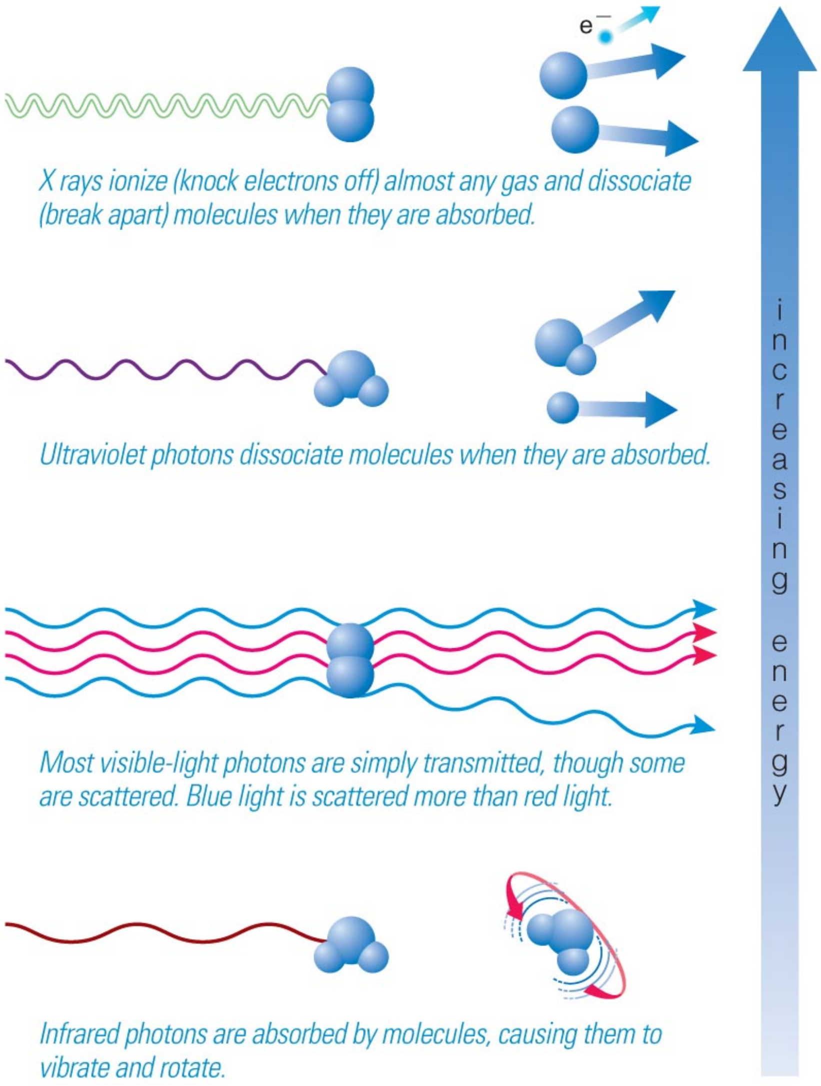
What would happen to Earth's temperature if Earth were more reflective?

a) It would go up.
b) It would go down.
c) It wouldn't change.

What do atmospheric properties vary with altitude?

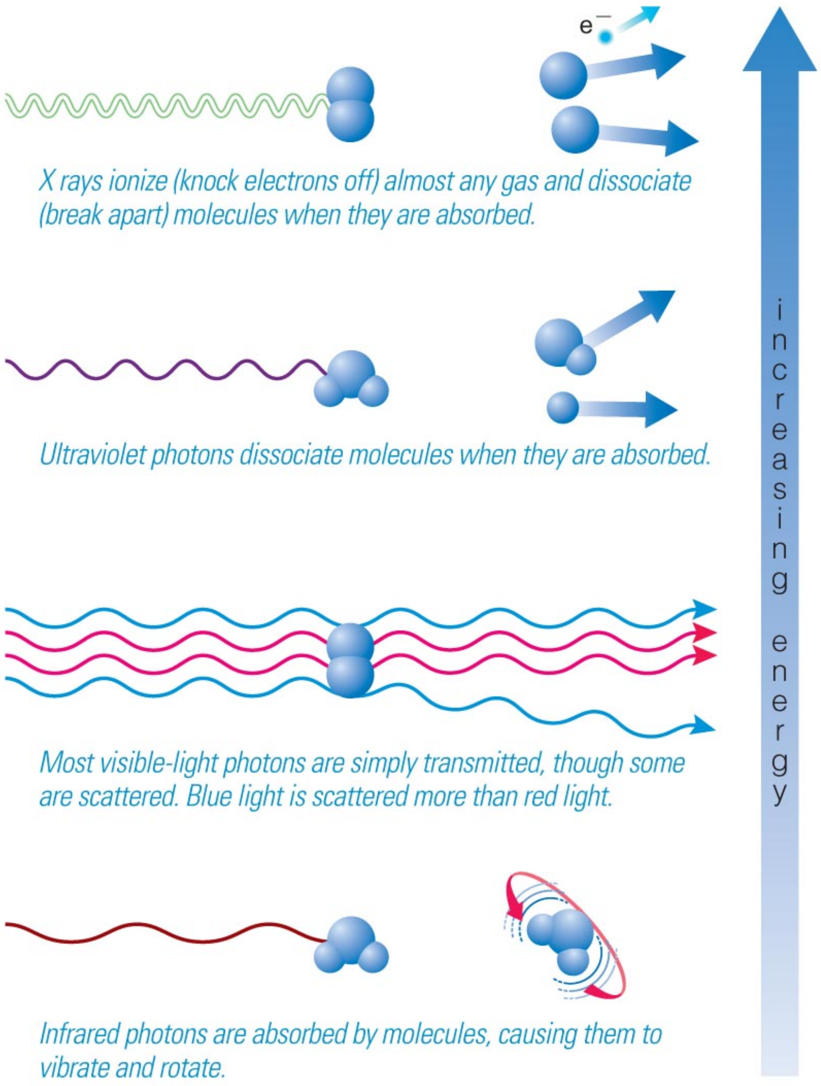


Light's Effects on Atmosphere



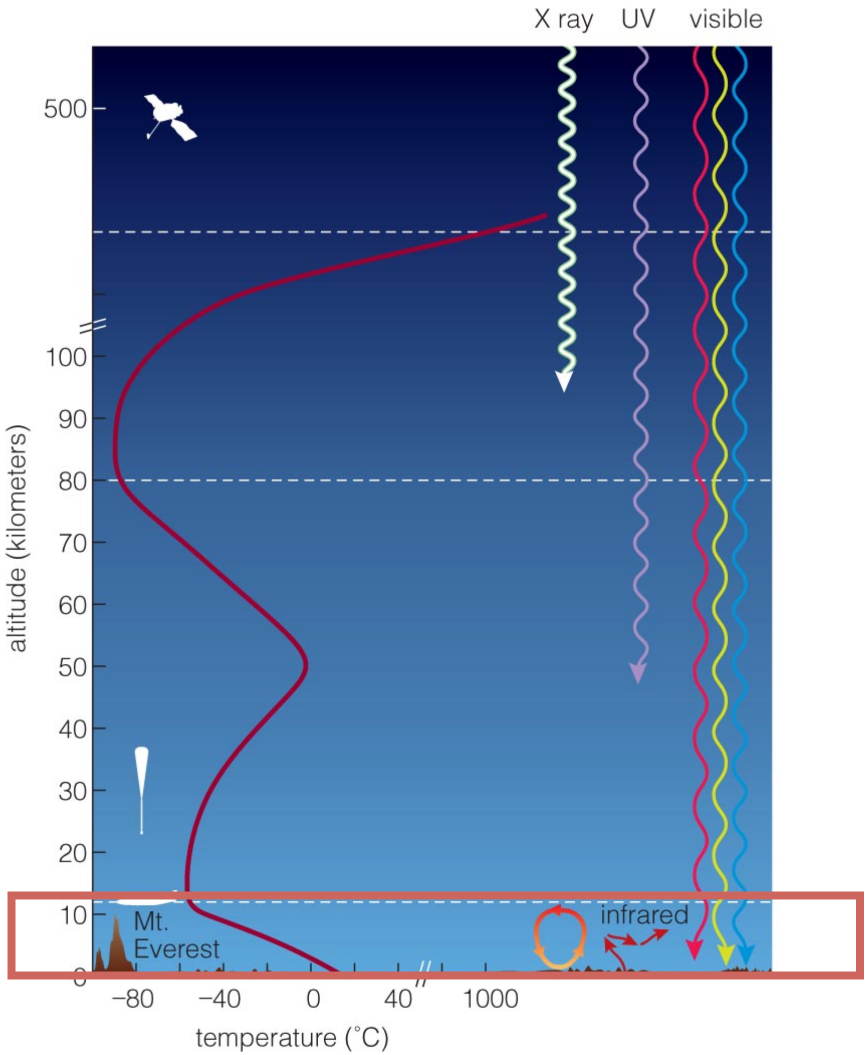
- **Ionization:** removal of an electron
- **Dissociation:** destruction of a molecule
- **Scattering:** change in photon's direction
- **Absorption:** photon's energy is absorbed.

Light's Effects on Atmosphere



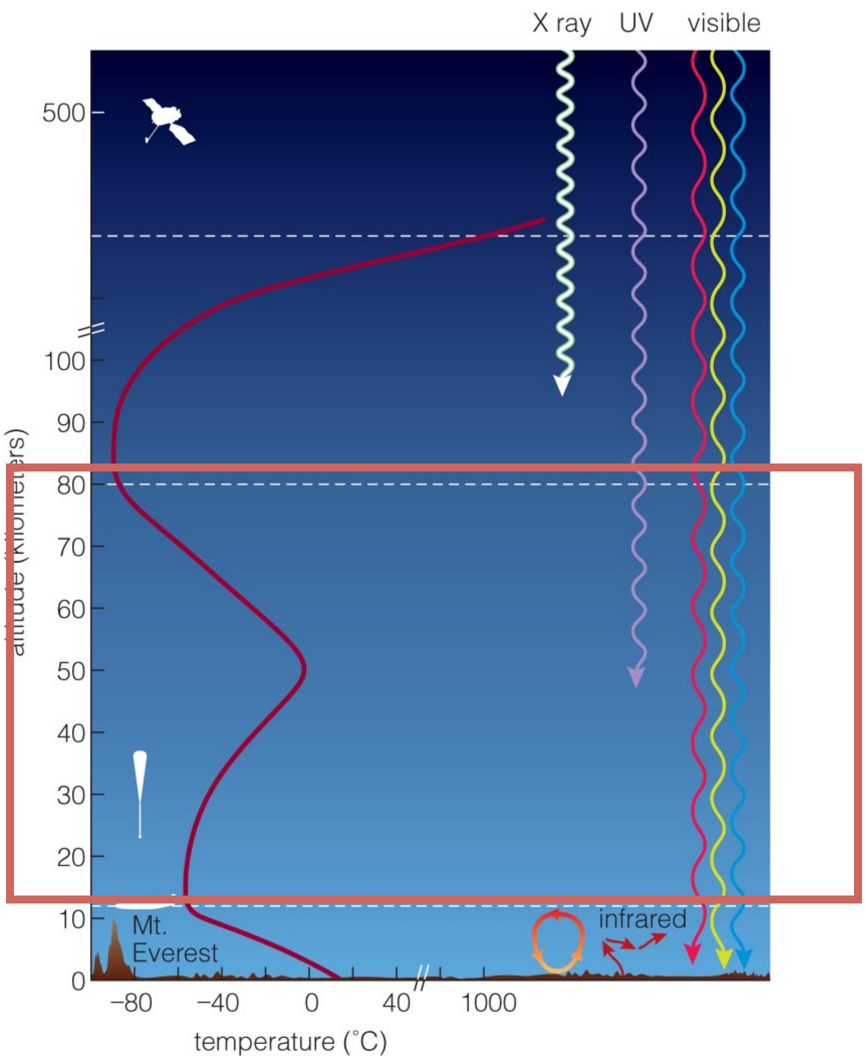
- X rays and UV light can ionize and dissociate molecules.
- Molecules tend to scatter blue light more than red.
- Molecules can absorb infrared light.

Earth's Atmospheric Structure



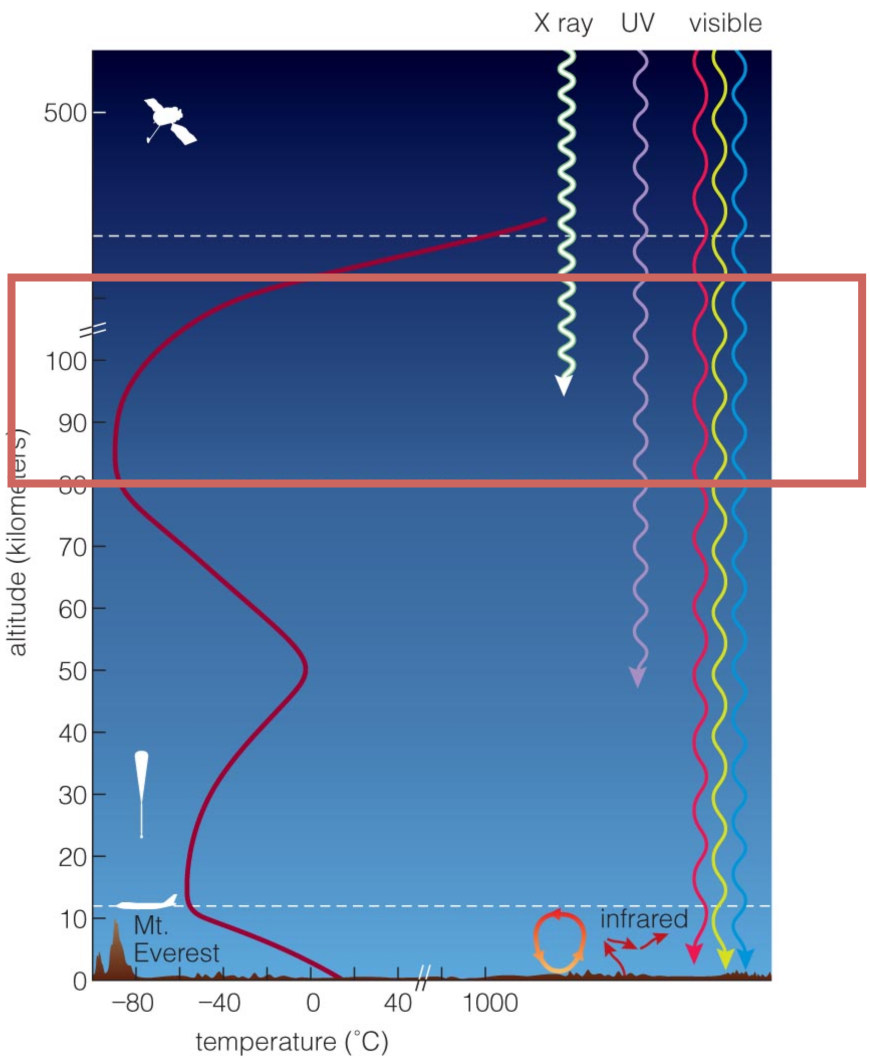
- **Troposphere:** lowest layer of Earth's atmosphere
- Temperature drops with increasing altitude.
- Warmed by infrared light from surface and convection

Earth's Atmospheric Structure



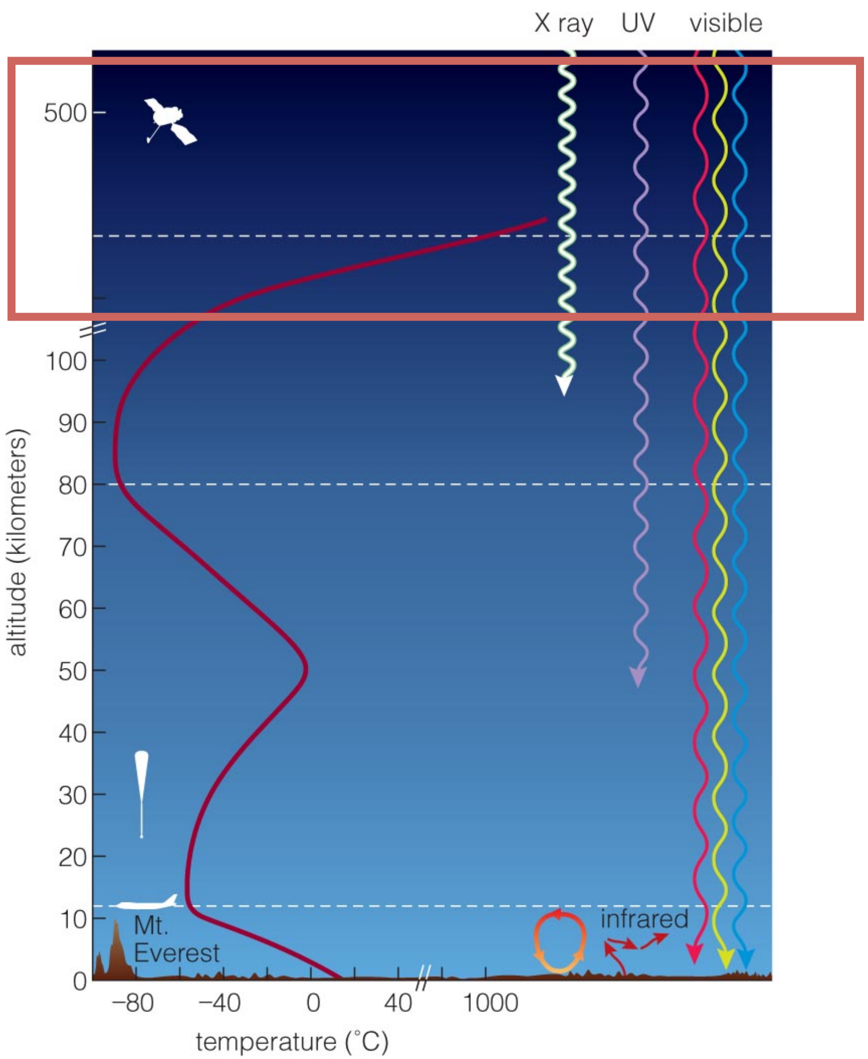
- **Stratosphere:** layer above the troposphere
- Temperature rises with altitude in lower part, drops with altitude in upper part.
- Warmed by absorption of ultraviolet sunlight

Earth's Atmospheric Structure



- **Thermosphere:** layer at about 100 kilometers altitude
- Temperature rises with altitude.
- X rays and ultraviolet light from the Sun heat and ionize gases.

Earth's Atmospheric Structure



- **Exosphere:** highest layer in which atmosphere gradually fades into space
- Temperature rises with altitude; atoms can escape into space.
- Warmed by X rays and UV light

Clicker Question

Why is the sky blue?

a) The sky reflects light from the oceans.
b) Oxygen atoms are blue.
c) Nitrogen atoms are blue.
d) Air molecules scatter blue light more than red light.
e) Air molecules absorb red light.

Clicker Question

Why is the sky blue?

a) The sky reflects light from the oceans.
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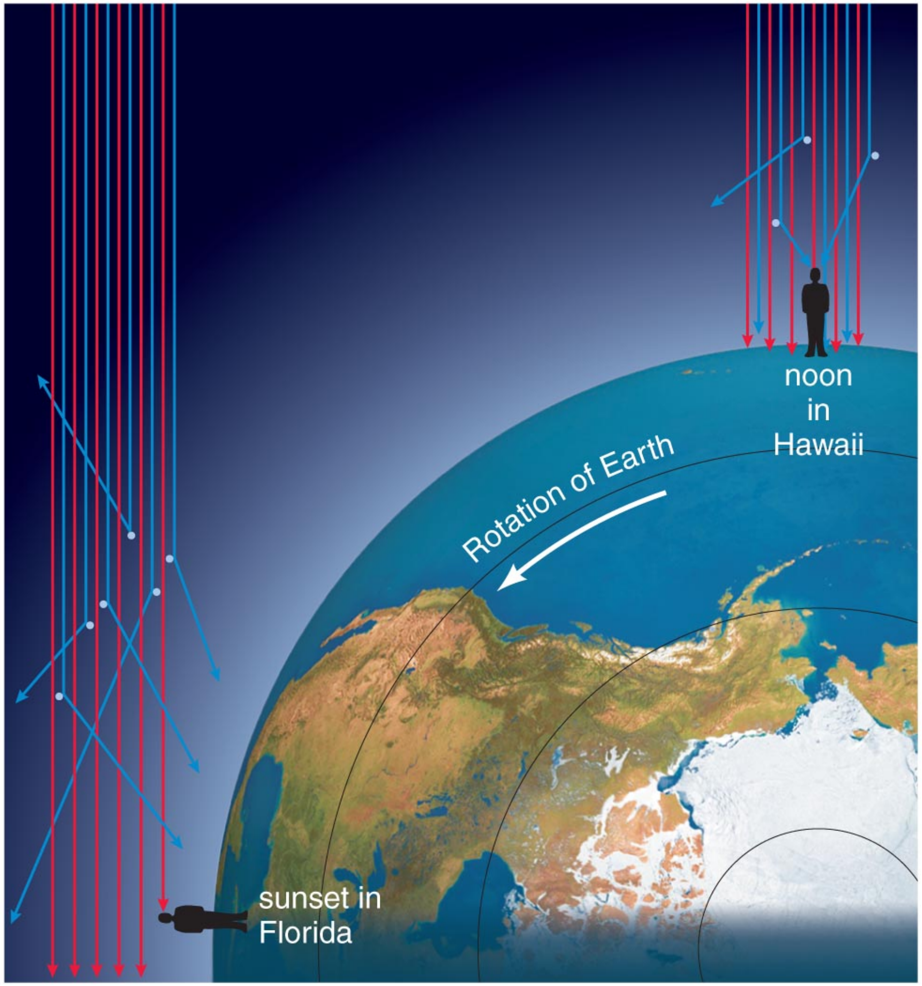
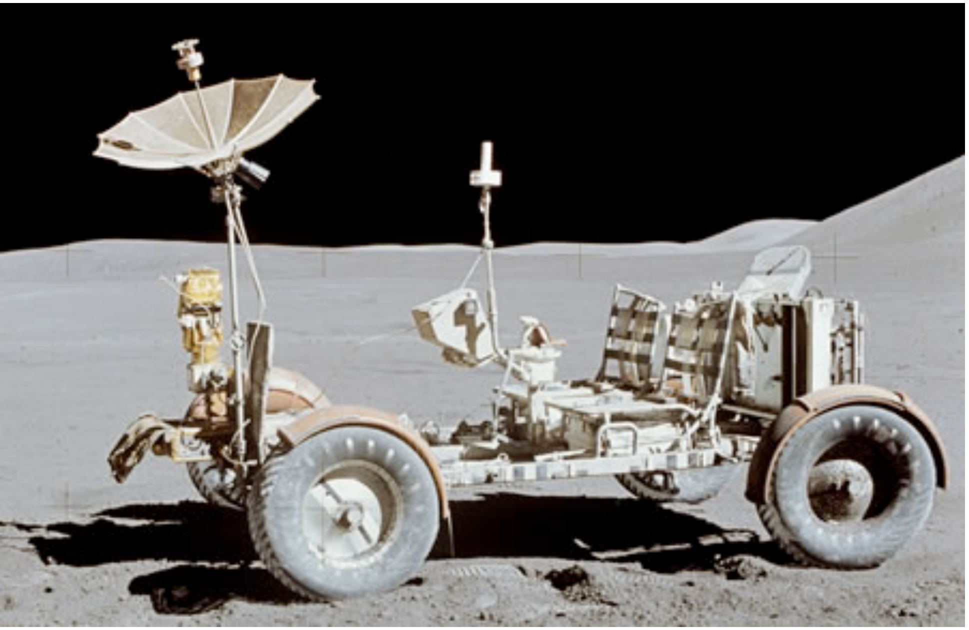
Why the Sky Is Blue



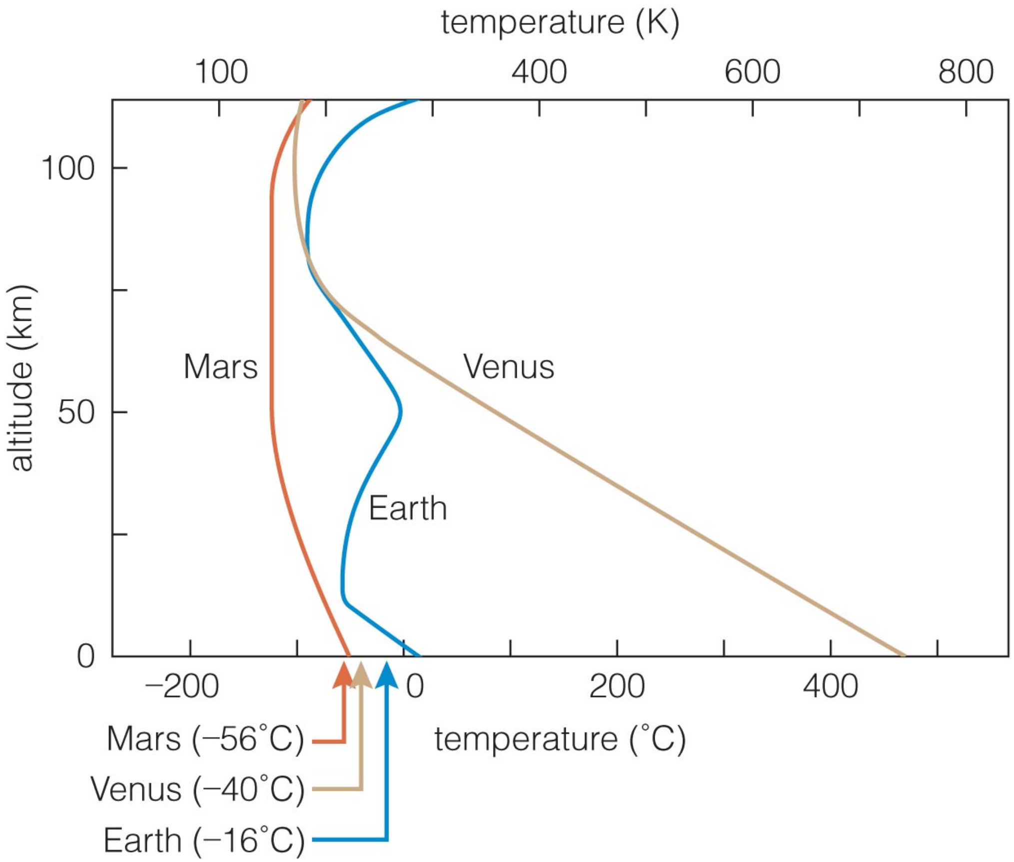
- Atmosphere scatters blue light from Sun, making it appear to come from different directions.
- Sunsets are red because red light scatters less.



Why the Sky Is Blue

- Atmosphere scatters blue light from Sun, making it appear to come from different directions.
- If there is no atmosphere, the sky is black

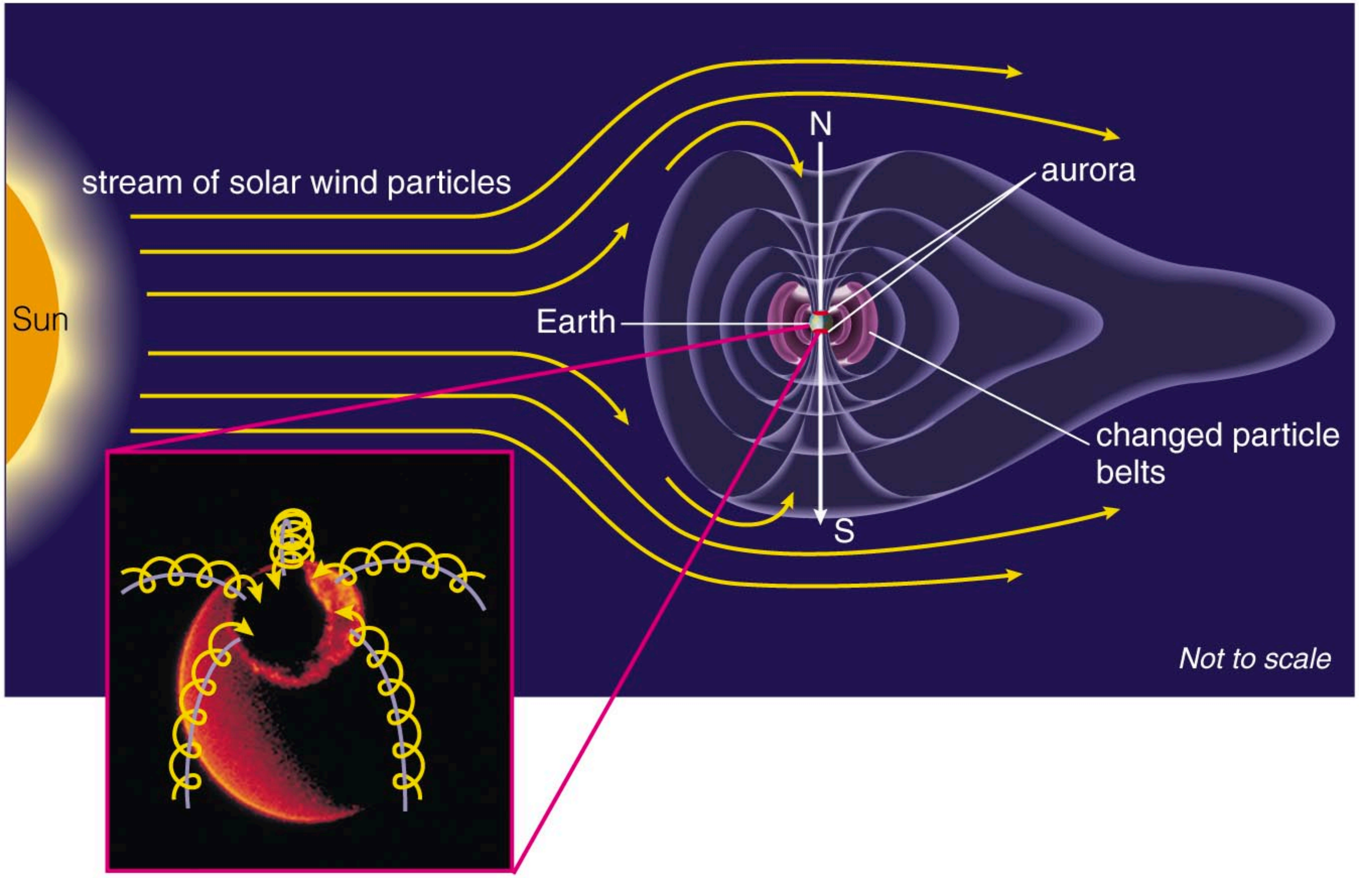
Atmospheres of Other Planets



“No greenhouse” temperatures

- Earth is only planet with a stratosphere because of UV-absorbing ozone molecules (O_3).
- Those same molecules protect us from Sun’s UV light.

Earth's Magnetosphere



- Magnetic field of Earth's atmosphere protects us from charged particles streaming from Sun (the solar wind).

Aurora

- Charged particles from solar wind energize the upper atmosphere near magnetic poles, causing an aurora.