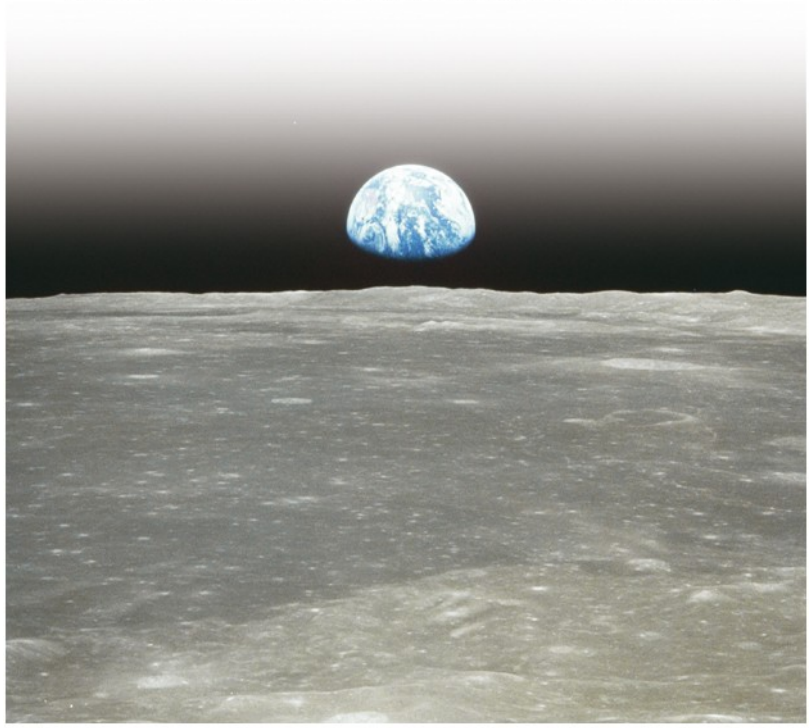
Chapter 2: Earth in Space

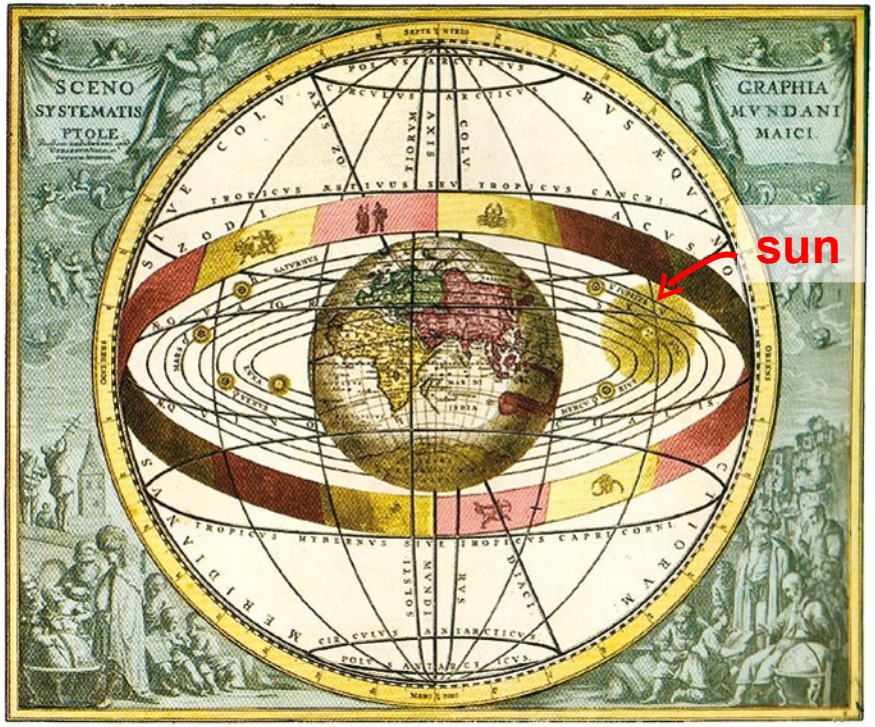
Old Ideas, New Ideas



"Earthrise" taken by astronauts aboard Apollo 8, December 1968

- Why is Earth the only planet known to support life?
- How have our views of Earth's position in space changed over time?
- Why is it warmer in summer and colder in winter? (or, How does Earth's position relative to the sun control the climate?)

Old Ideas, New Ideas



Earth pictured at the center of a geocentric planetary system

From a Geocentric to Heliocentric System

- **Geocentric orbit hypothesis** - Ancient civilizations interpreted rising of sun in east and setting in west to indicate the sun (and other planets) revolved around Earth
  - Remained dominant idea for more than 2,000 years

Old Ideas, New Ideas

From a Geocentric to Heliocentric System

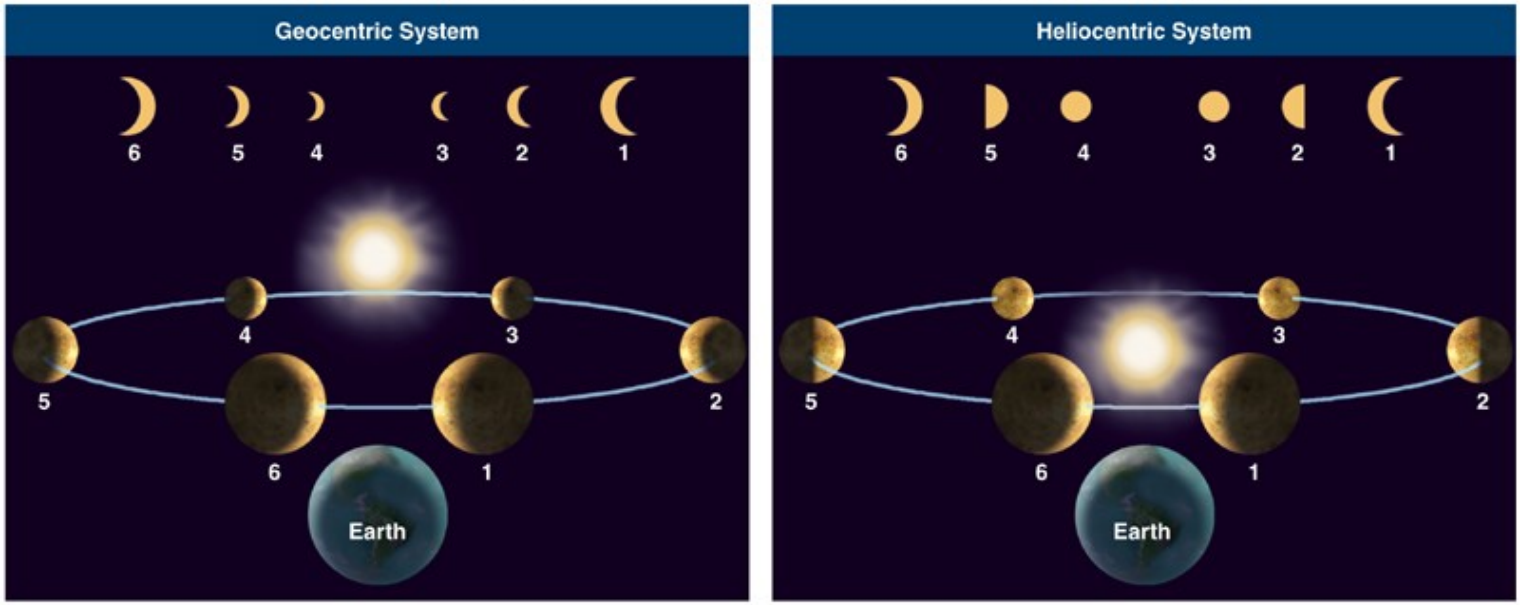
- **Heliocentric orbit hypothesis** – 16th century idea suggested by Copernicus
- Confirmed by Galileo's early 17th century observations of the phases of Venus
  - Changes in the size and shape of Venus as observed from Earth

a.

Old Ideas, New Ideas

From a Geocentric to Heliocentric System

- Galileo used early telescopes to observe changes in the size and shape of Venus as it revolved around the sun



b.

Earth in Space Conceptest

The moon has what type of orbit?

A. **Geocentric**

B. Heliocentric

C. Neither

Origin of the Universe

Earth, a small, rocky planet, orbits the

. . . the **sun**, a medium sized star,

. . one of billions of stars in the **Milky Way galaxy**, .

. one of billions of galaxies in the **universe**.

© NASA

Earth in Space Conceptest

Which of the following statements is true?

A. All stars and planets are about the same age.

B. **Stars are approximately the same age as their orbiting planets – a little older**

C. The number of stars is declining as stars burn out.

Go to the next section: ***Our Solar System***

Earth in Space Quiz

What are the principal components of the sun?

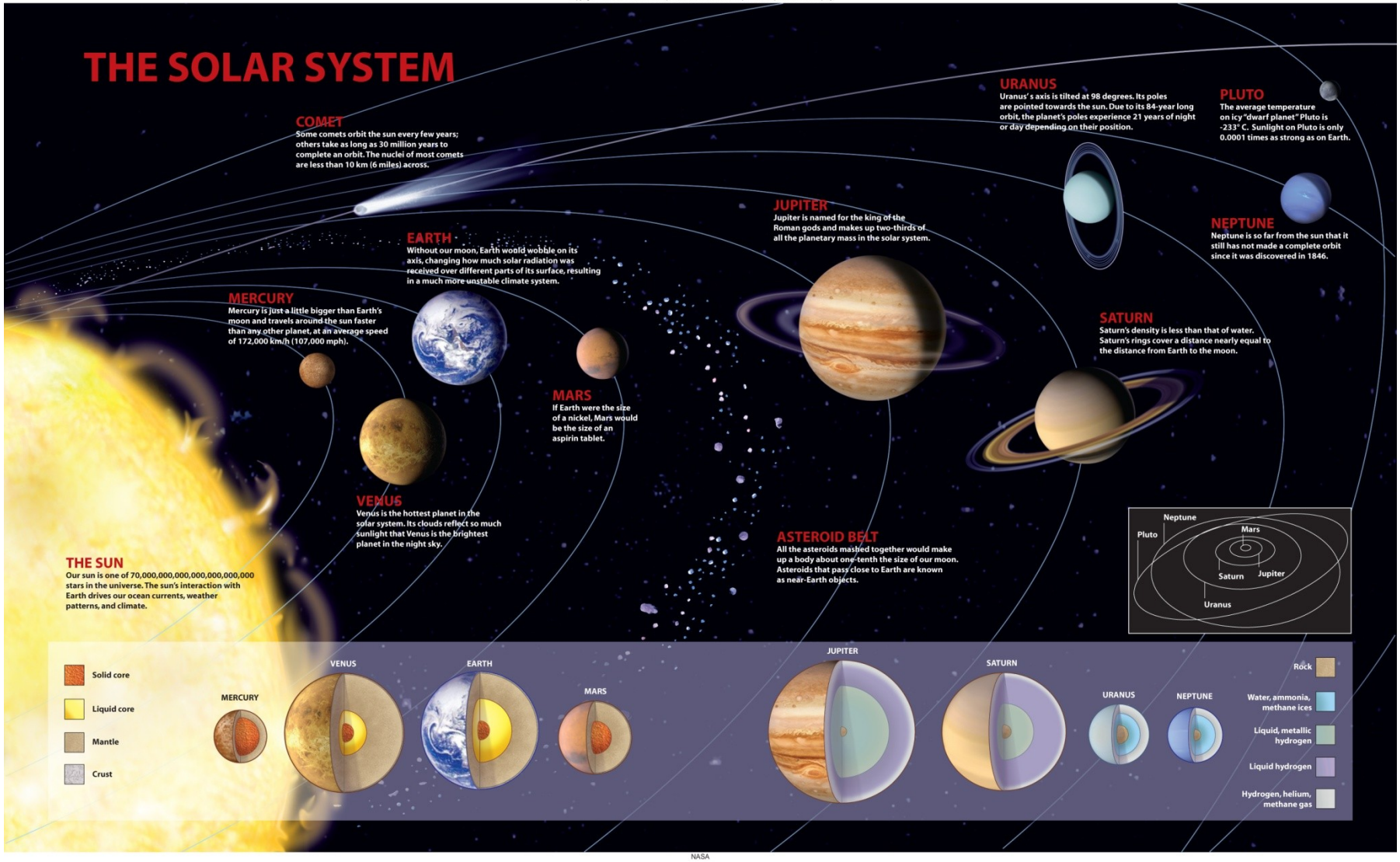
A. **Hydrogen and helium**

B. Carbon and oxygen

C. Silicon and nitrogen

D. Nickel and iron

Our Solar System



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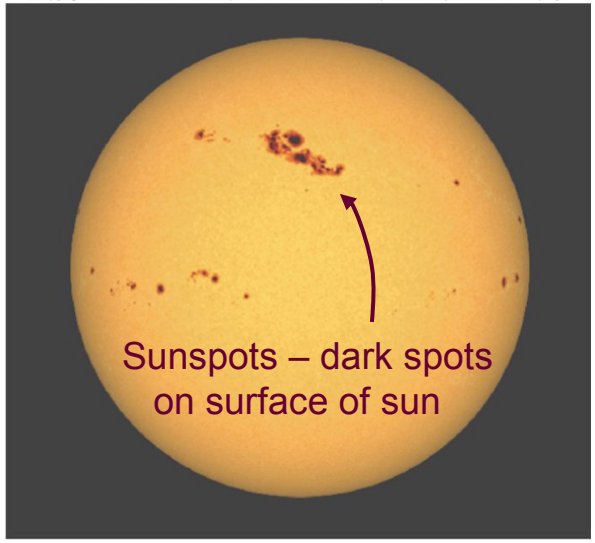
Our Solar System



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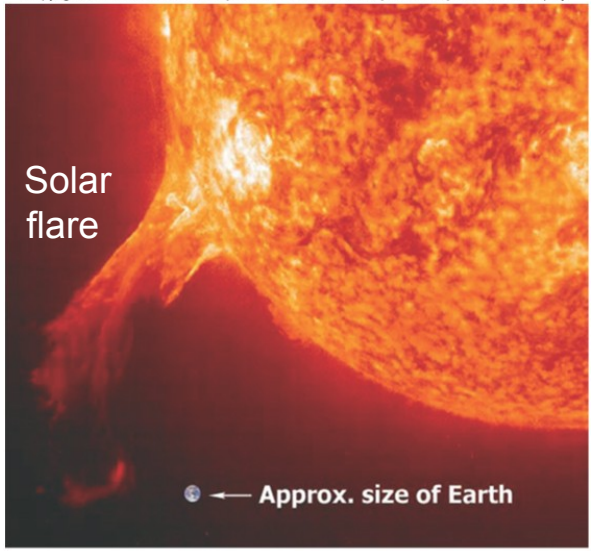
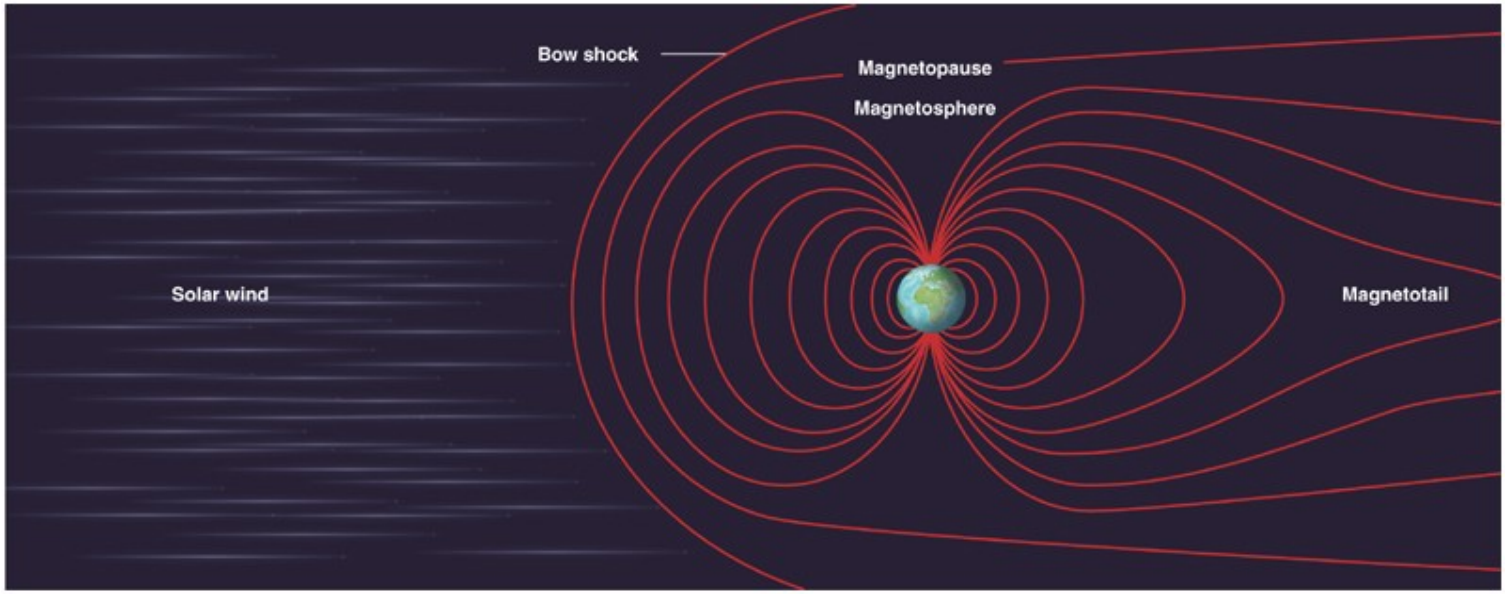


c.

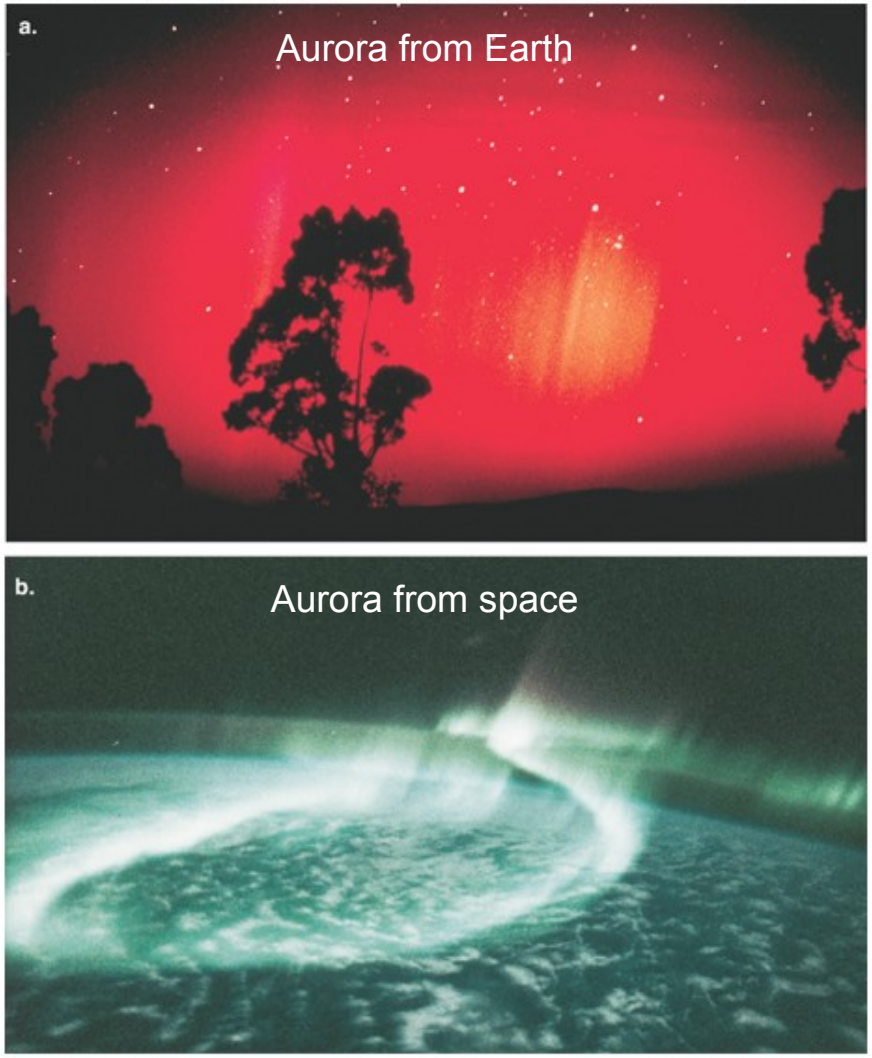
- Solar system - sun and surrounding planets
- Sun = 99.8% of total mass of the solar system
  - Sun 150,000,000 km from Earth
- Sun undergoes differential rotation
  - Sun's equatorial region rotates faster (25 days) than polar regions (36 days)
  - Results in disruption of sun's magnetic field to produce **sunspots** and **solar flares**

Our Solar System

- The **solar wind** is a stream of charged particles emitted from sun's magnetic field (1,600,000 km/hr)
- The solar wind affects an volume of space known as the **heliosphere**
- Earth's magnetic field deflects the solar wind



Our Solar System



© NOAA National Geophysical Data Center, NASA

- Interactions of solar wind with Earth's magnetic field generates **aurora** in the upper atmosphere of polar regions
- Occasional solar eruptions can disrupt Earth's magnetic field to produce electrical blackouts
  - Satellites in greater danger from solar flares than features on surface

Earth in Space Conceptest

The sun is located approximately 150,000,000 km from Earth. All disturbances travel with the speed of light – 300,000 km/s. H**ow long would it take energy released by a solar flare to affect electrical systems on Earth?**

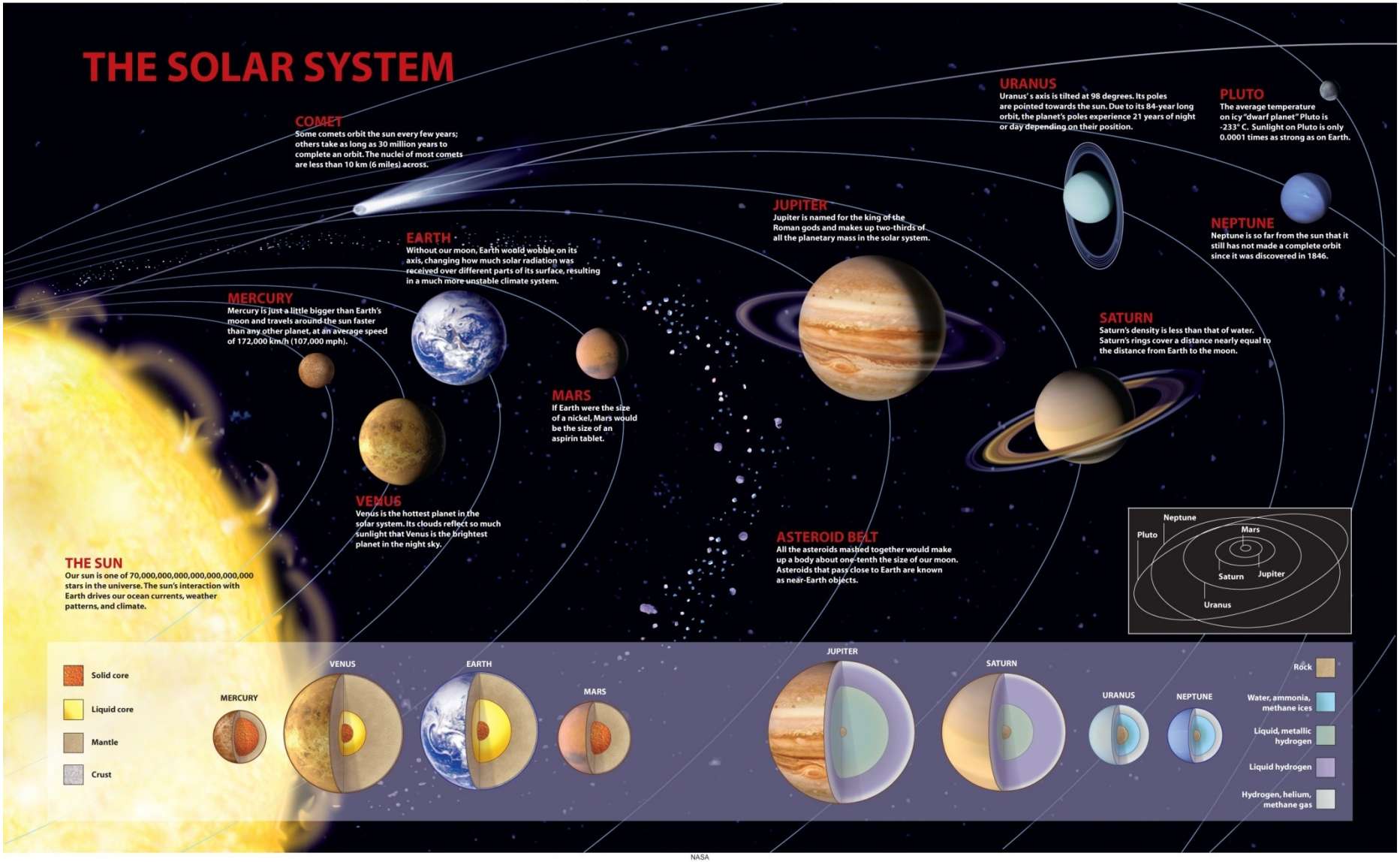
A. **A few minutes (~8 min)**

B. A few hours

C. A few days

D. A few weeks

Our Solar System



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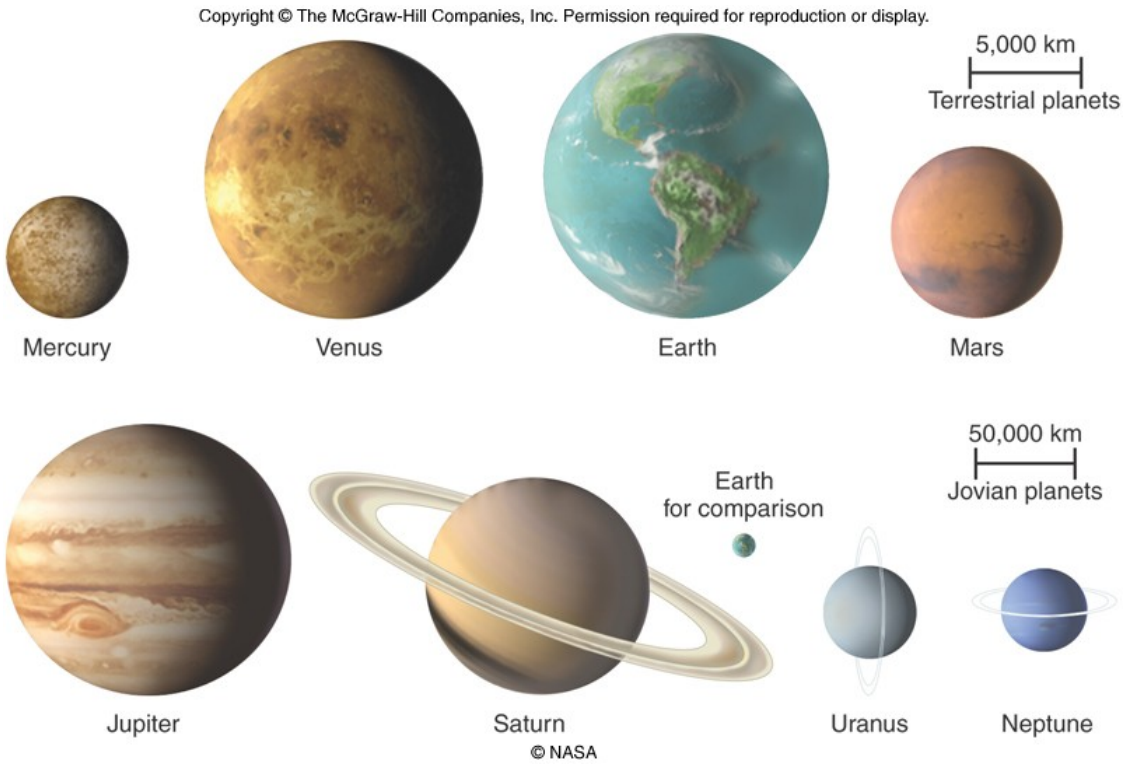
Our Solar System

Table 2.1 Characteristics of the 8 Planets

Planet	Size (radius), km	Orbital period	Distance from sun, million km [AU]	Principal atmospheric gases
Mercury	2,440	88 days	58 [0.4]	Helium, sodium
Venus	6,052	225 days	108 [0.7]	Carbon dioxide
Earth	6,378	365 days	150 [1]	Nitrogen, oxygen
Mars	3,397	687 days	228 [1.5]	Carbon dioxide
Jupiter	71,492	11.9 years	778 [5.2]	Hydrogen, helium
Saturn	60,268	29.5 years	1,427 [9.5]	Hydrogen, helium
Uranus	25,559	84 years	2,871 [19]	Hydrogen, helium
Neptune	24,746	165 years	4,497 [30]	Hydrogen, helium

Our Solar System



Eight Planets

- 4 terrestrial planets (Mercury, Venus, Earth, Mars)
- Jovian planets (Jupiter, Saturn, Uranus, Neptune)

Our Solar System

What about Pluto?

- Improved technology resulted in recent discoveries of several distant objects that were similar size or larger than Pluto
- International Astronomical Union (IAU) could either
  1. Consider the new objects as new planets

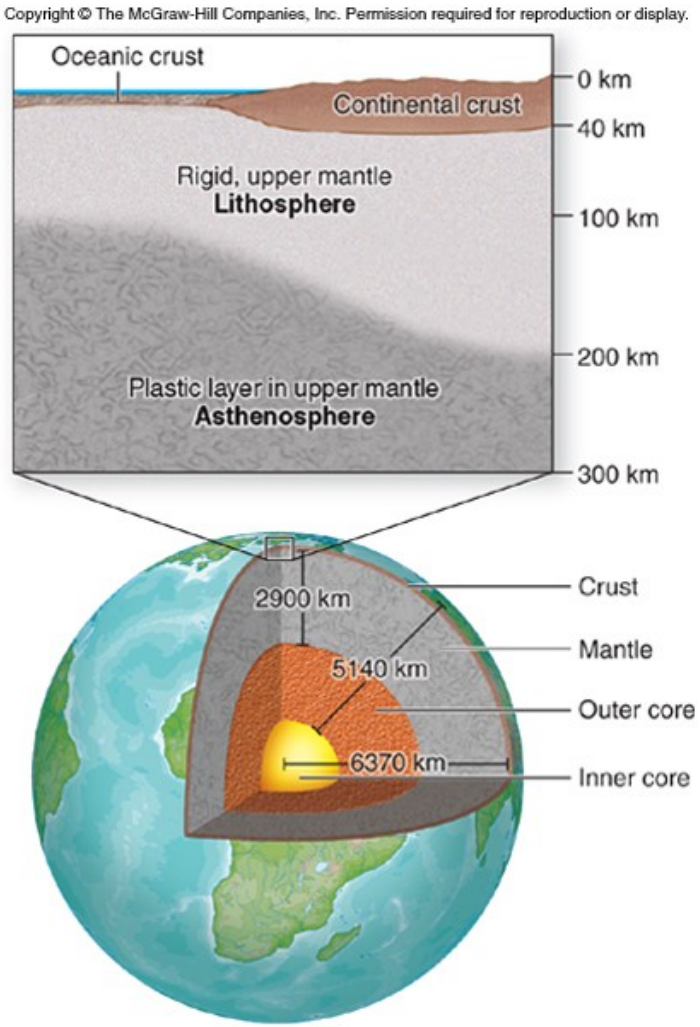
     OR

  2. Classify the new objects – and Pluto – as a new group of objects
- IAU chose option #2 – Pluto is a “dwarf planet”

Our Solar System

Terrestrial Planets

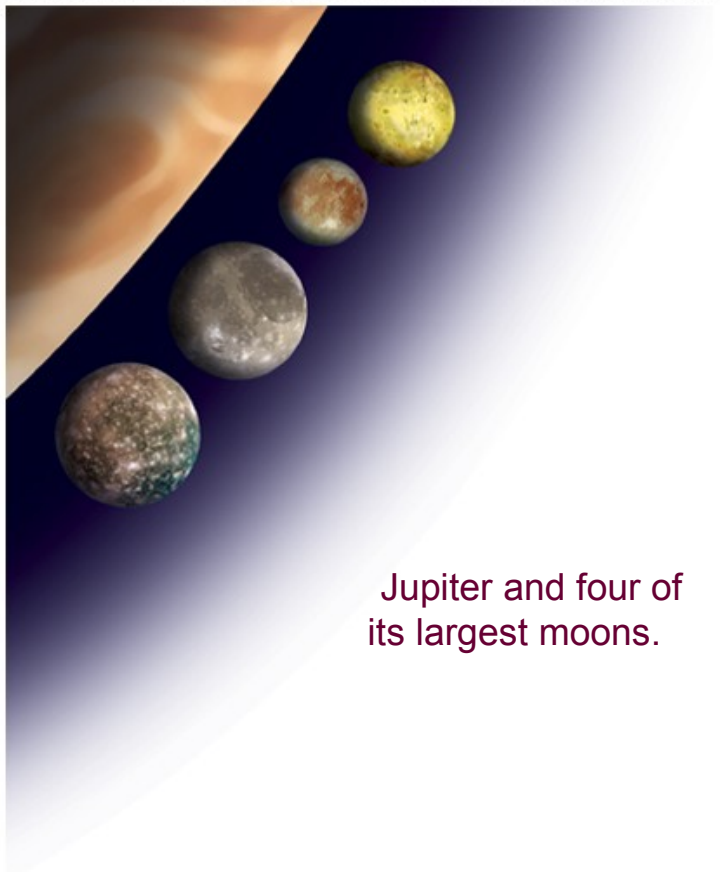
- Composed of rocks
- Divided into compositional layers
  - Crust – composed of lighter elements (e.g., silicon, oxygen)
  - Mantle
  - Core – composed of heavier elements (e.g., iron, nickel) found in metallic meteorites



Our Solar System

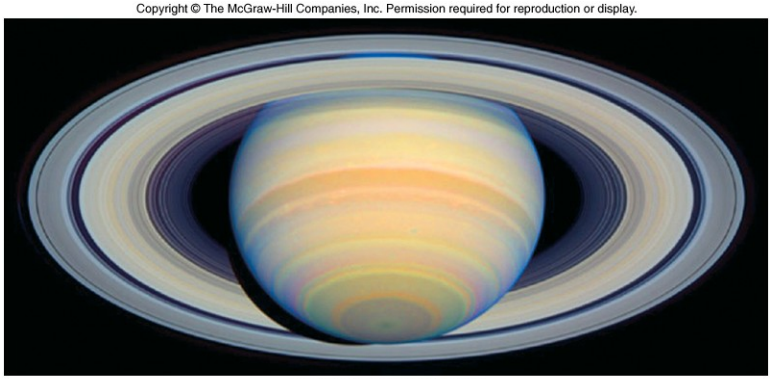
Jovian Planets

- Large, gas giants
- Much of the volume of the planets is a thick atmosphere overlying oceans of liquid gases
- Characterized by many moons and ring systems



Jupiter and four of its largest moons.

© NASA / JPL



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Saturn's ring system. The gravitational pull of the moon's keep the ring systems in place.

Go to the next section: ***Earth, the Sun, and the Seasons***

Earth, the Sun, and the Seasons

What patterns must the Earth-Sun relationship be able to explain?

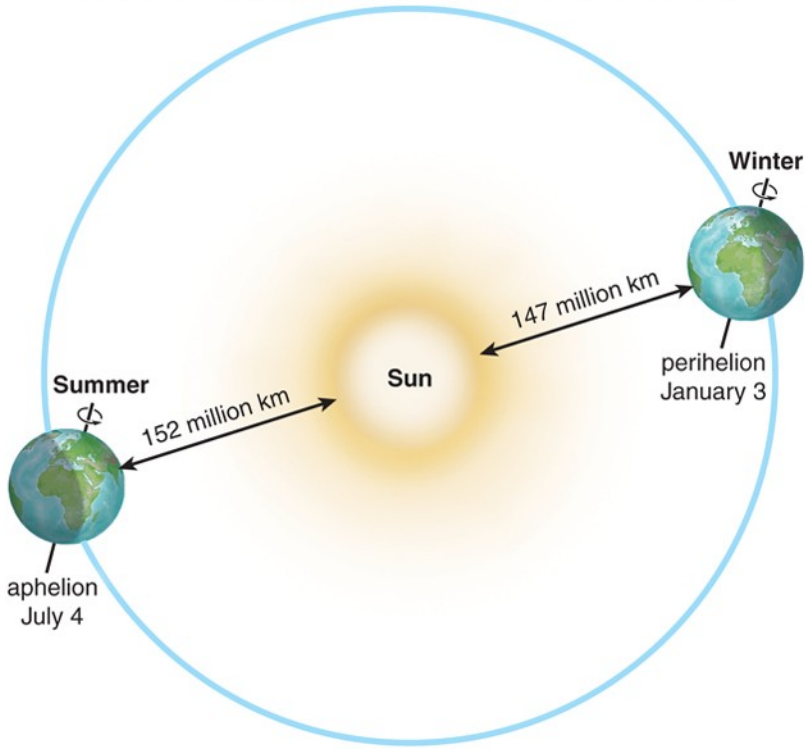
- Why is it hotter at the equator and colder at the Poles?
- Why is it colder in winter (January) than in summer (July)?
- Why is it summer in Australia when it is winter in the U.S.?

Earth, the Sun, and the Seasons

Why is it colder in winter and warmer in summer?

- Common misconception that Earth is closer to the sun during summer and farther away in winter

- But Earth is actually closer to sun in winter (in the northern hemisphere) and farther away in summer.

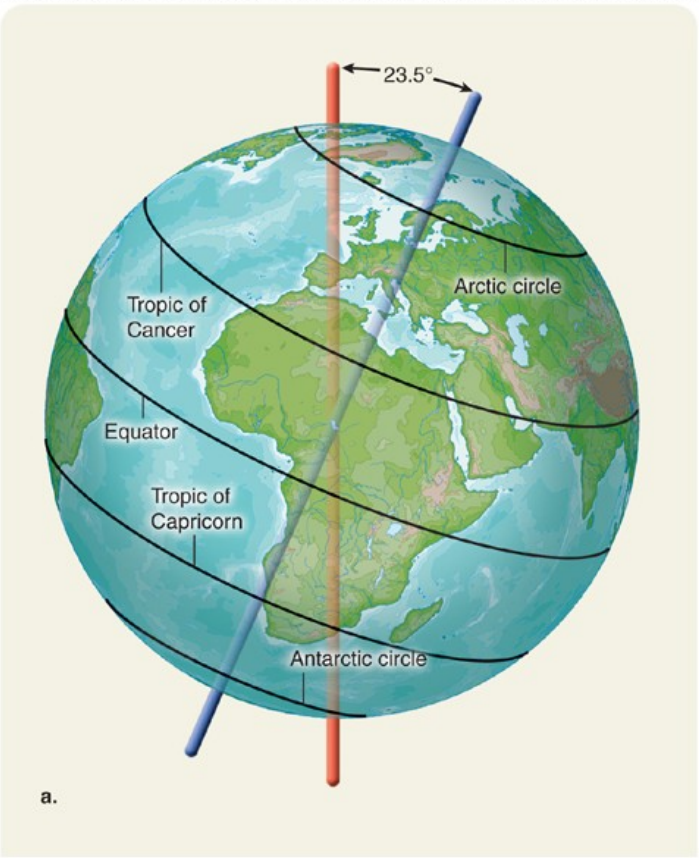


Distance from sun does not contribute to temperature differences between winter and summer

Earth, the Sun, and the Seasons

Why is it colder in winter and warmer in summer?

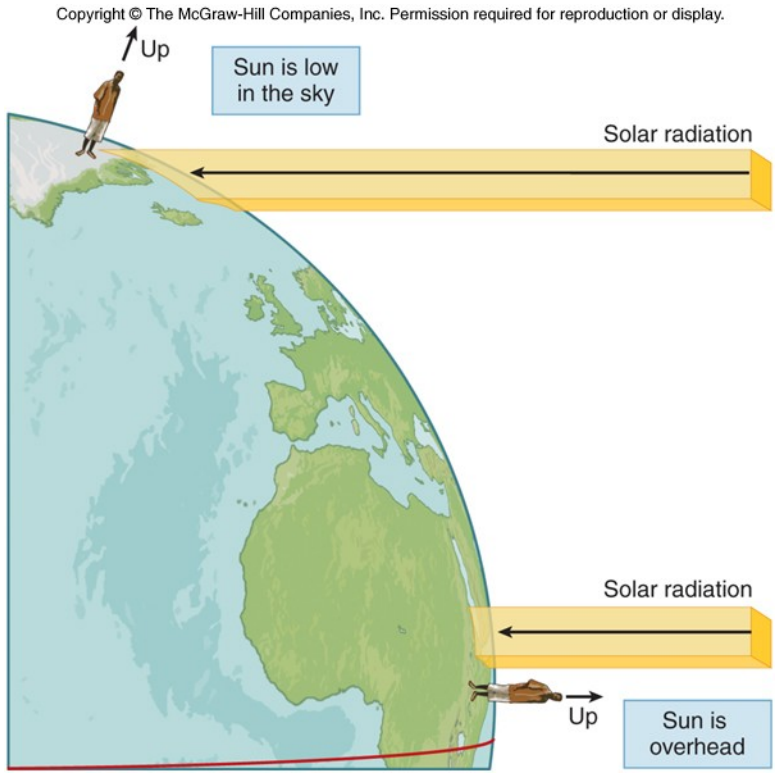
- Seasonal temperature contrasts are due to the tilt of Earth's axis and angle of Sun's rays
  - Tilt = 23.5 degrees



Earth is tilted on an imaginary axis oriented 23.5 degrees to vertical. The tropics of Cancer and Capricorn are 23.5 degrees of latitude north and south of the equator.

Earth, the Sun, and the Seasons

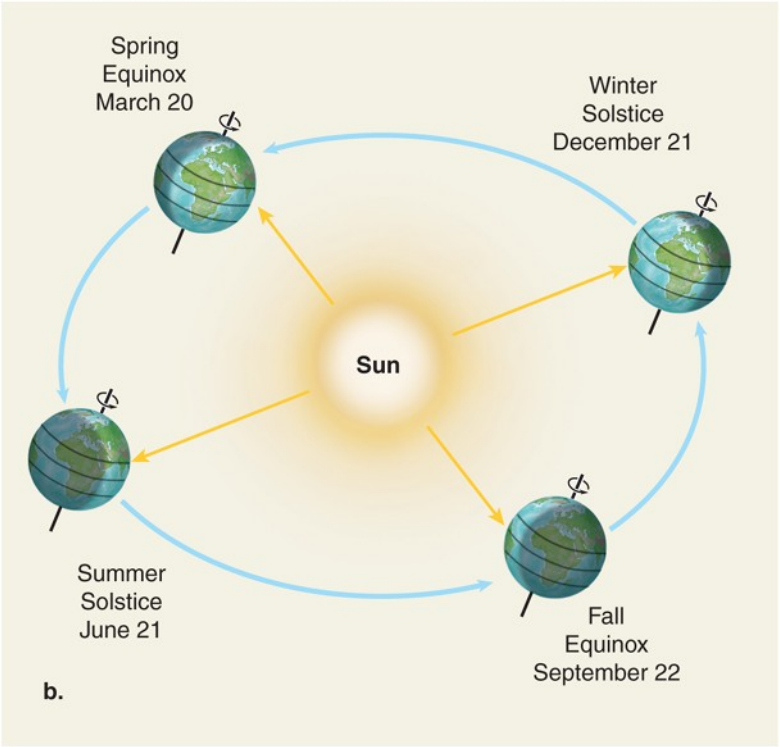
- Amount of solar energy (insolation) reaching Earth's surface depends on the angle the Sun's rays strike Earth
- More heat delivered by insolation where the Sun is directly overhead
  - As sunlight is distributed over a smaller area
  - Total annual insolation is least at Poles, greatest at the Equator



Solar energy is diluted over a larger area when sunlight strikes at a low angle (at high latitudes).

Earth, the Sun, and the Seasons

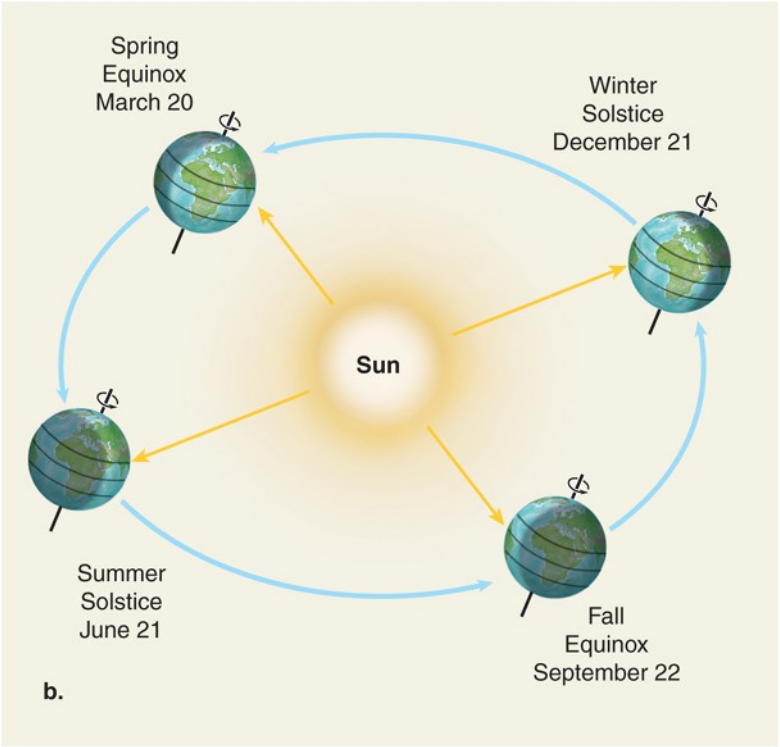
- Sun is directly overhead at different places (tropics, equator) during different seasons
  - During summer in the northern hemisphere, the sun is directly overhead at the Tropic of Cancer
  - During winter in the northern hemisphere, the Sun is directly overhead at the Tropic of Capricorn in the southern hemisphere



Note that **Earth's axis is always tilted in the same direction** causing the distribution of solar radiation to change with the seasons.

Earth, the Sun, and the Seasons

- Sun is directly overhead at different places (tropics, equator) during different seasons
  - During spring and fall in the northern hemisphere, the sun is directly overhead at the Equator

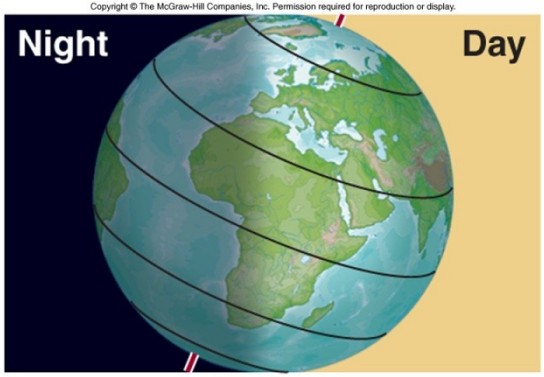


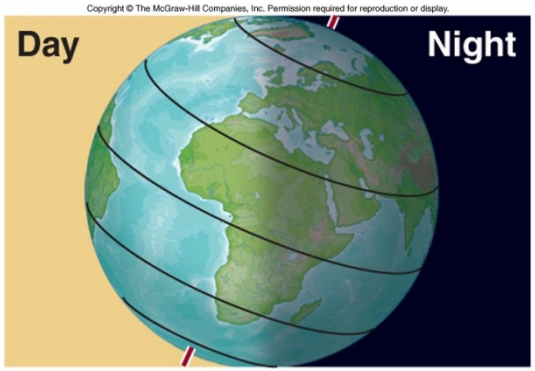
Note that **Earth's axis is always tilted in the same direction** causing the distribution of solar radiation to change with the seasons.

Earth, the Sun, and the Seasons

Why day length changes

- Hours of daylight change
  - With latitude – higher latitudes have more daylight than low latitudes in summer, less in winter
  - With time of year – all locations have more daylight in summer and less in winter





High latitudes in the Northern Hemisphere experience nearly continuous daylight in summer (top) and almost perpetual darkness in winter.

Earth in Space Conceptest

How would the amount of incoming solar radiation (power density watts/m^2) change at the equator if Earth's axis was vertical instead of tilted?

A. Incoming solar radiation would decrease.

B. Incoming solar radiation would be the same as at present.

C. Incoming solar radiation would increase. (same power but area decreases – higher power density → higher temperature)

Earth in Space Conceptest

What would happen to the average temperature at the equator during our summer if the tilt angle of Earth's axis increased to 27º?

A. **Temperatures would decrease (power density decreases)**
B. Temperatures would increase
C. Temperatures would stay the same

We get warmer when the power density from sunlight increases.

Earth in Space Conceptest

What must happen to the tilt angle of Earth's axis in order to have vertical rays where you live on the summer solstice (June 21)? Sun is directly overhead in Newark.

A. Tilt would increase

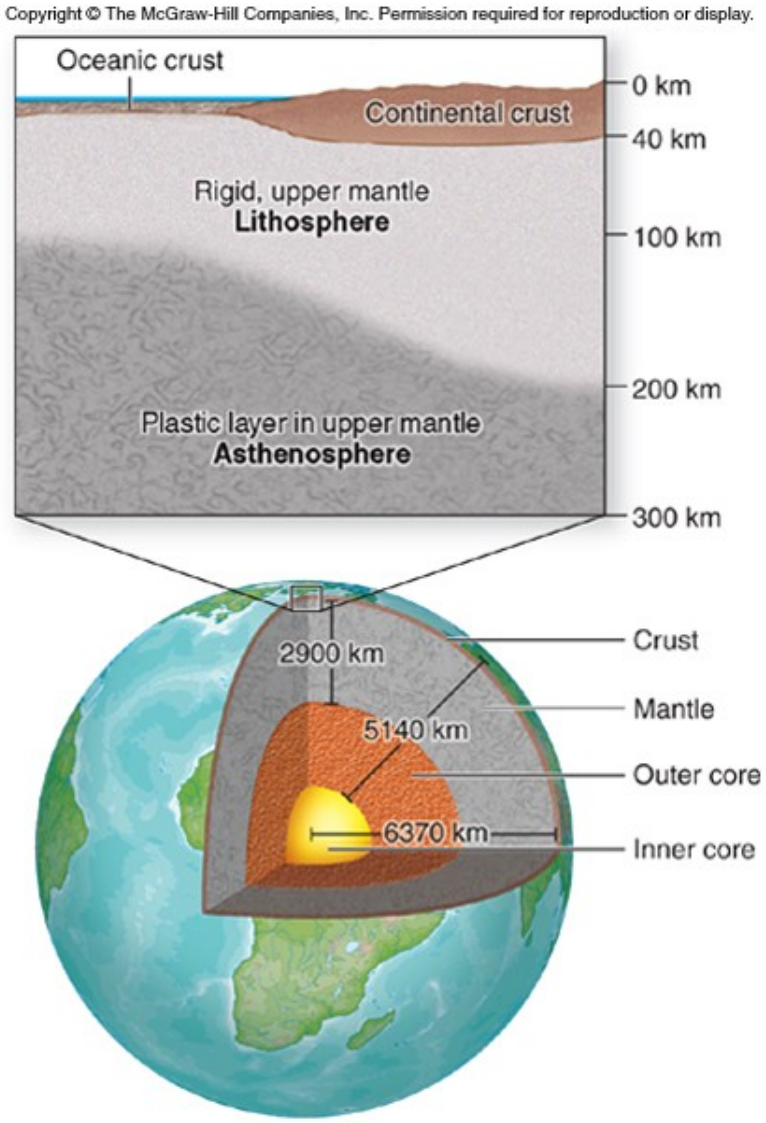
B. Tilt would decrease

C. Tilt would stay the same

Go to the next section: ***The Unique Composition of Earth***

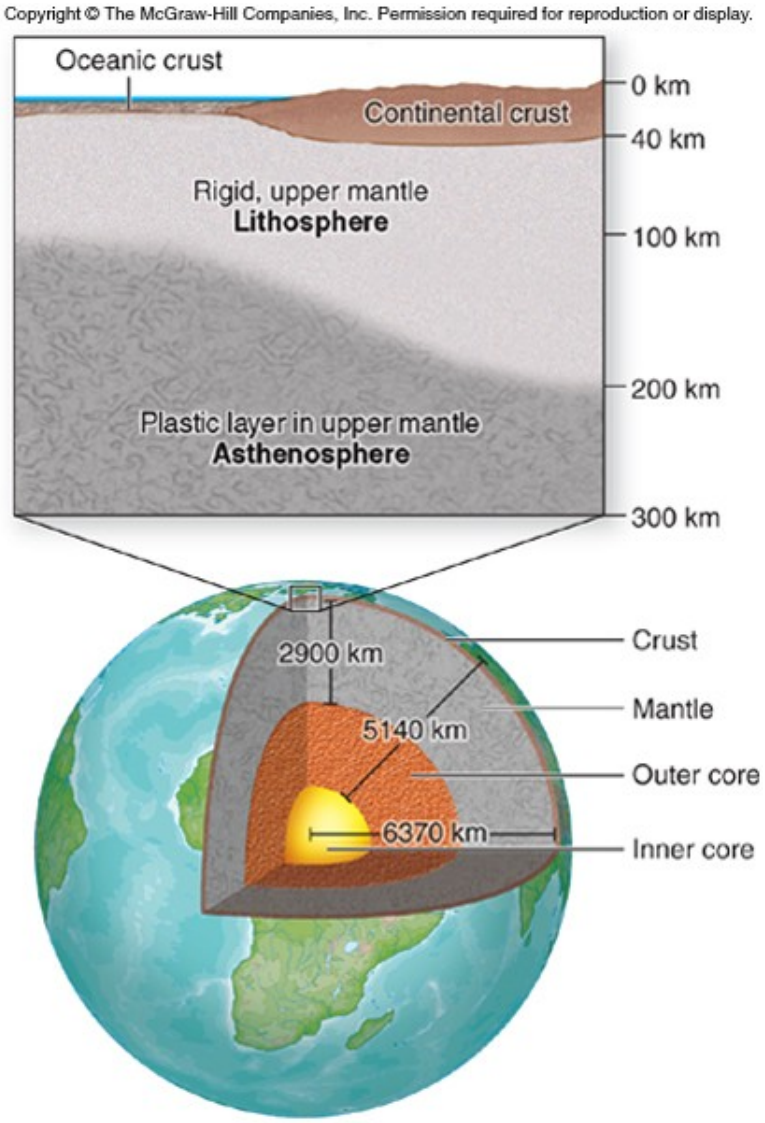
The Unique Composition of Earth

- Earth's interior can be divided into three major compositional layers
  - Crust – composed of lighter elements (e.g., silicon, oxygen)
  - Mantle – composed of rocks made up of 3 key elements (oxygen, silicon, magnesium)
  - Core – iron and nickel
    - solid inner core
    - partially melted outer core is source of Earth's magnetic field



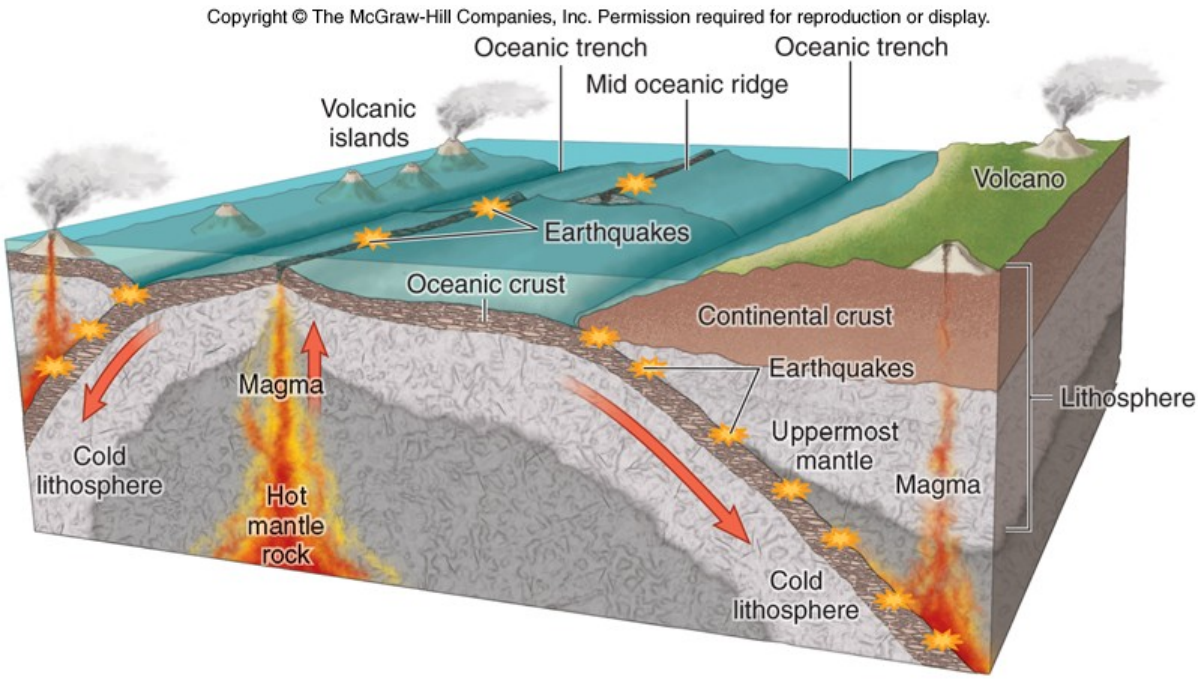
The Unique Composition of Earth

- Scientists recognize two layers with different properties near the surface
  - Lithosphere – rigid outer layer composed of crust and upper mantle
  - Asthenosphere – plastic, slowly flowing layer in uppermost part of mantle



The Unique Composition of Earth

- Lithosphere divided into large slabs known as tectonic plates
  - Plates move over Earth's surface to produce earthquakes, volcanoes, mountain belts, and various features on the seafloor

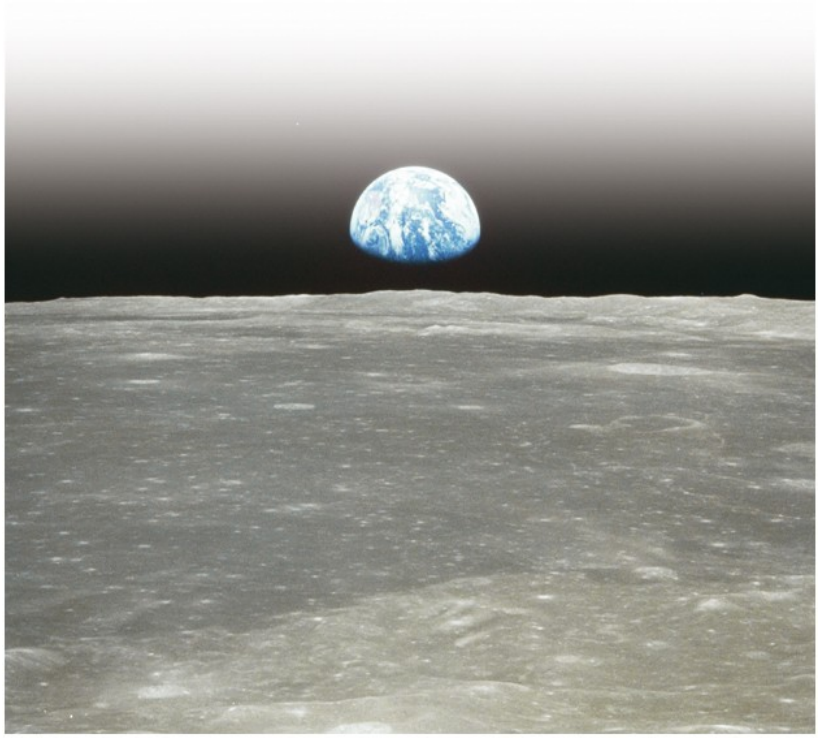


The Unique Composition of Earth

Geothermal gradient

- Earth's temperature increases with depth
  - Average temperature rise is 25°C/kilometer
- Heat generated by the:
  - Formation of the planet – all terrestrial planets cooled following formation
    - Only large planets still retain heat
  - Radioactive decay of elements in Earth's interior

The Unique Composition of Earth



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Earth shares many features with other planets, so what makes it so special?

- Liquid water
- Gravity and a protective atmosphere
- Life-sustaining gases
- A strong magnetic field

The Unique Composition of Earth

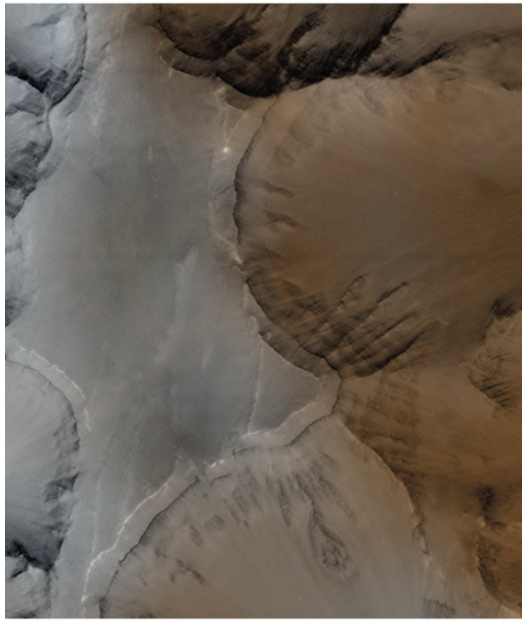
Liquid water is essential for life on Earth and is maintained by appropriate temperature range (0-100°C)

Venus

- Too close to Sun, original water evaporated to atmosphere
- Water vapor molecules (H_2O)split by ultraviolet radiation and hydrogen lost to space
- O combines with Fe (reddish surface).
- Volcanoes emit greenhouse gas. H combines with S and O – Sulfuric Acid rain

Mars

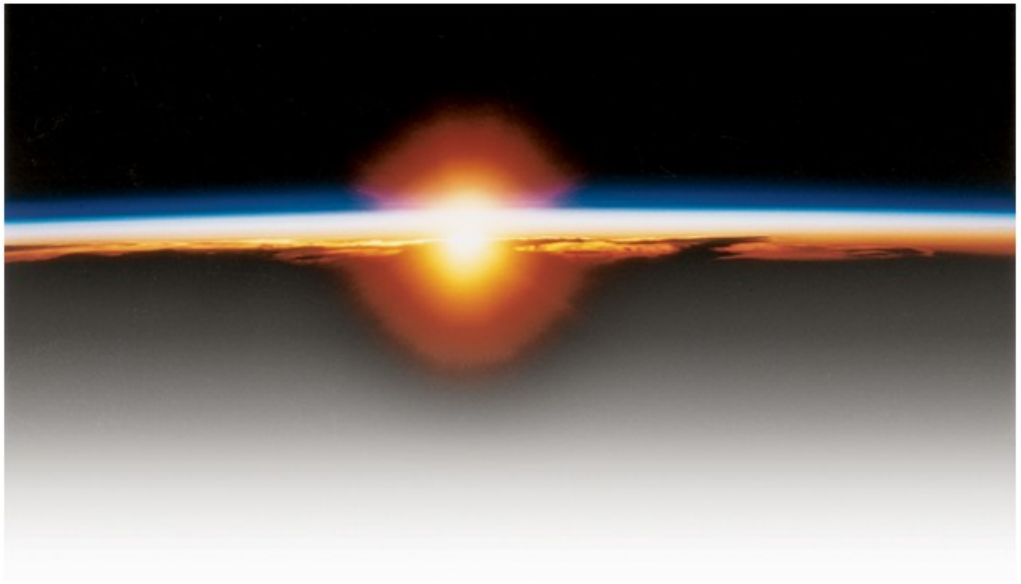
- Too cold today to have liquid water, some frozen
- Smaller than Earth, cooled to solid core, no magnetic field, no atmosphere



Courtesy of Malin Space Science Systems/ NASA

Image of Mars suggests there may have once been liquid water on Mars

The Unique Composition of Earth



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Earth's size is sufficient to produce enough gravity to hold a **thick atmosphere of gases** in place (rotation and liquid core)

Atmosphere protects us from:

- Incoming asteroids/comets
- Harmful solar radiation (x-rays, UV)

The Unique Composition of Earth

Earth's biosphere has altered the composition of the atmosphere to add oxygen and extract toxic carbon dioxide

Atmosphere composition effects temperature:

- Higher carbon dioxide (greenhouse gas) content on Venus produces temperatures of 464^{o}C
- Compare to average Earth temperature ~60^{o}F (~15^{o}C)

The Unique Composition of Earth

Composition of Earth's atmosphere just right to absorb enough heat to keep average temperature of 15°C

Greenhouse effect:

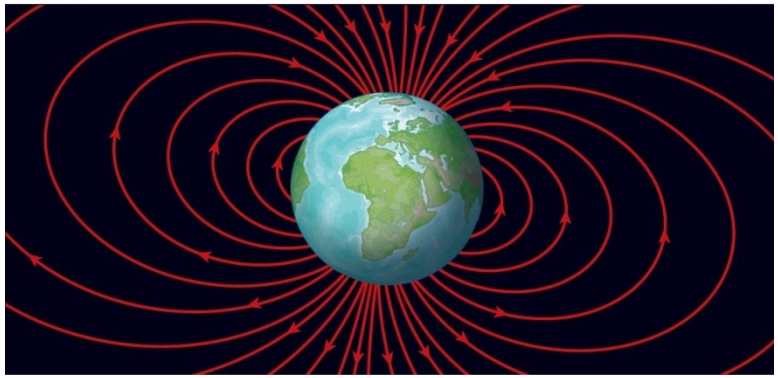
- Water vapor, carbon dioxide (0.038%) gases absorb heat
- Without greenhouse effect, temperatures would be -18°C

The Unique Composition of Earth

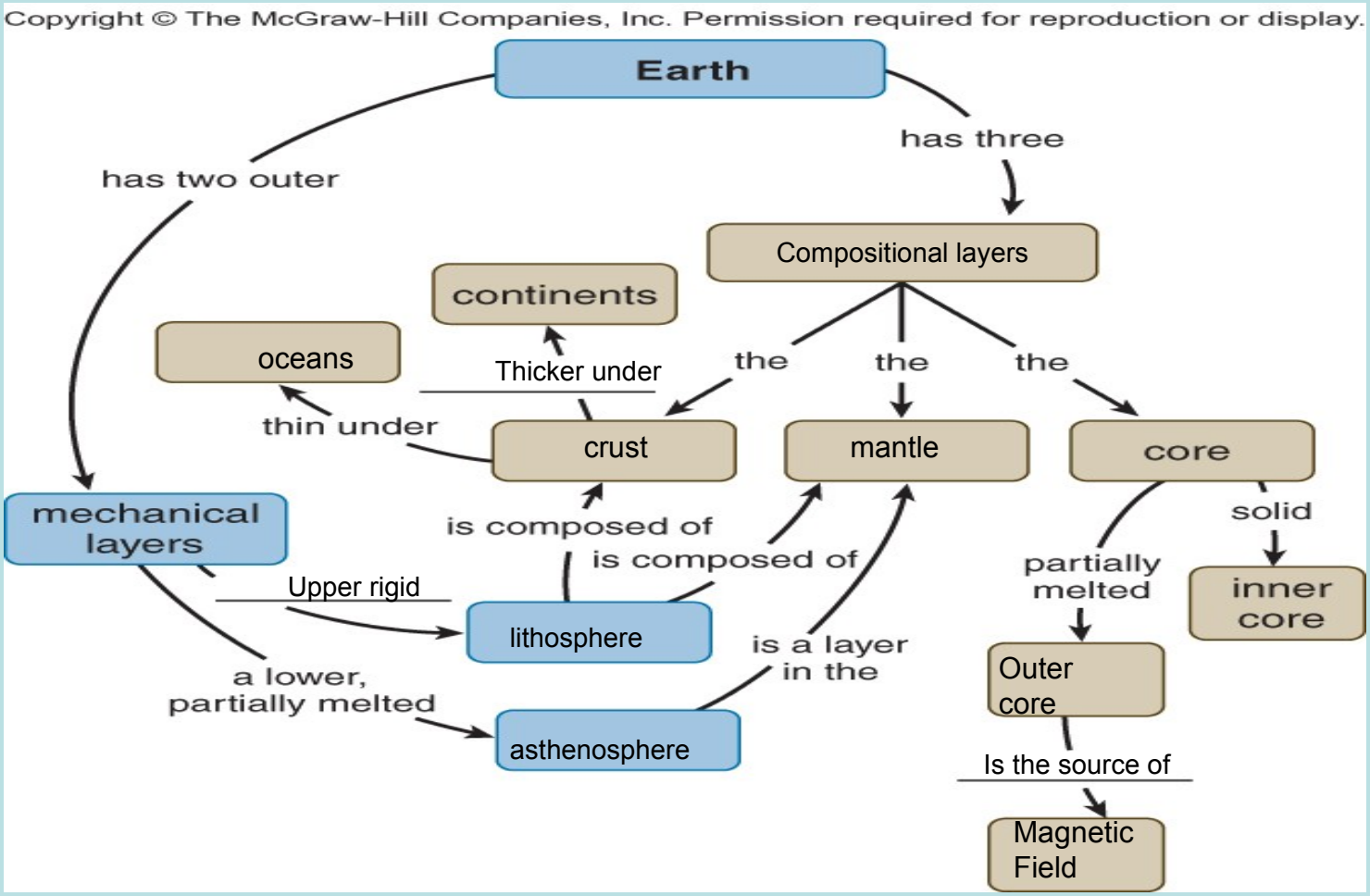
Earth's magnetic field protects Earth from harmful solar wind that would strip away atmosphere

Magnetic field due to molten rocks in the outer core and relatively rapid planetary rotation:

- Smaller planets or slowly rotating planets have lost heat and have weak magnetic fields



Complete the concept map by placing words or phrases where needed.



Earth in Space Conceptest

If Earth were farther from the sun, the planet would be, _____.

A. warmer
B. colder

Earth in Space Conceptest

If Earth's biosphere were younger, we would have _____ oxygen in the atmosphere. (Oxygen in atmosphere is a result of life.)

A. less
B. more

Earth in Space Conceptest

If Earth were smaller, its atmosphere would be _____. (Gravitational force keeps atmosphere size. Larger mass has more gravitational force.)

A. thicker
B. thinner

The End