2.1 Patterns in the Night Sky

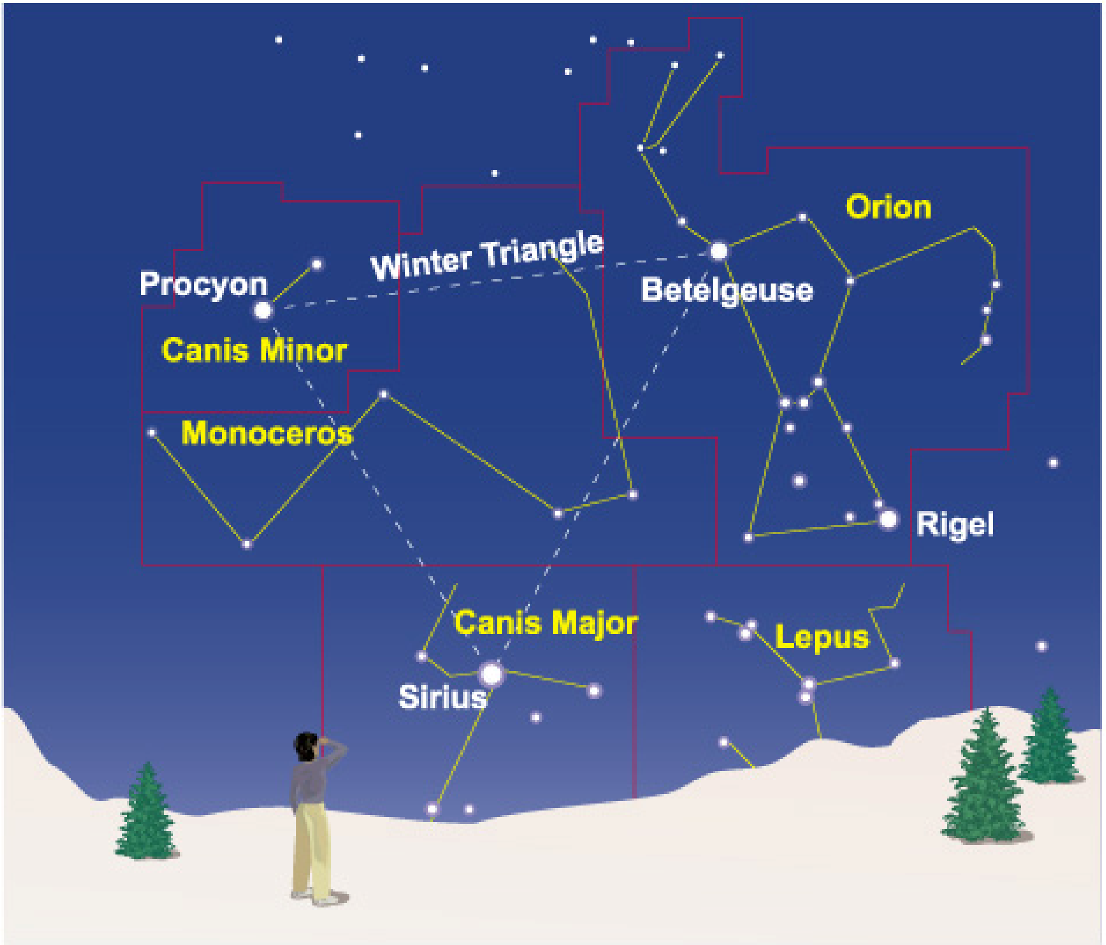
Our goals for learning:

- What are constellations?
- How do we locate objects in the sky?
- Why do stars rise and set?
- Why don't we see the same constellations throughout the year?

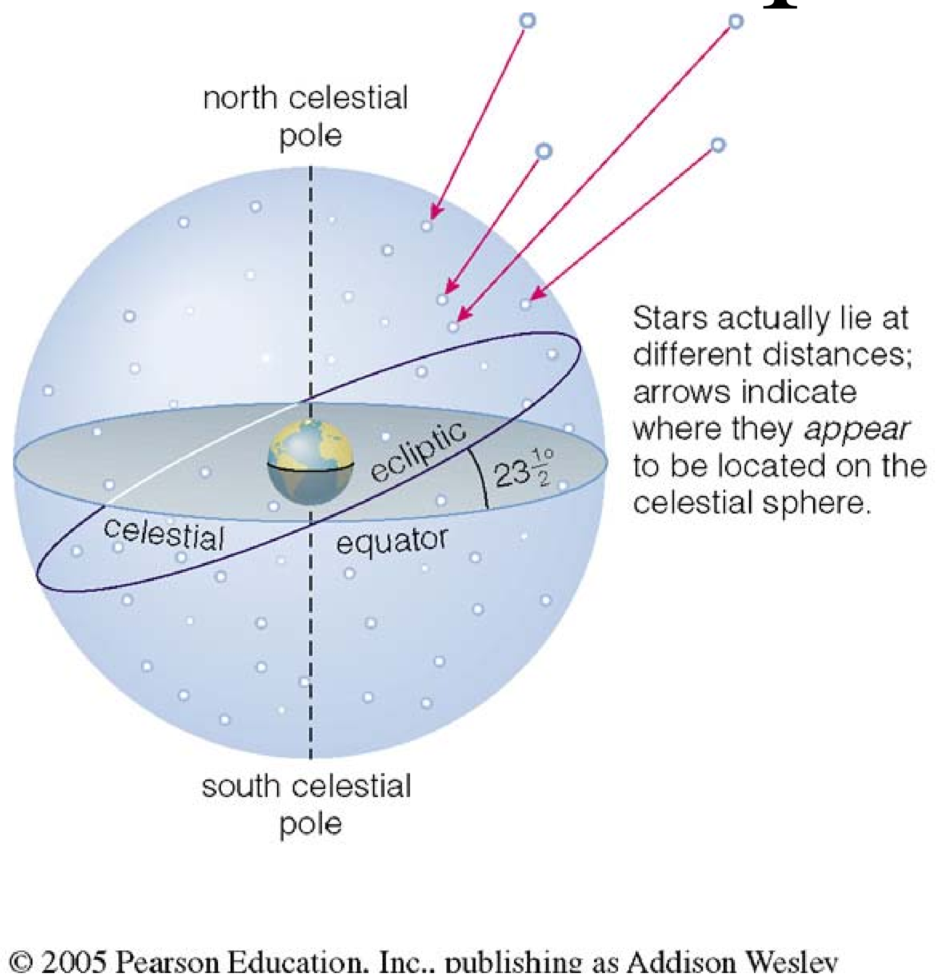
What are constellations?

A constellation is a *region* of the sky.

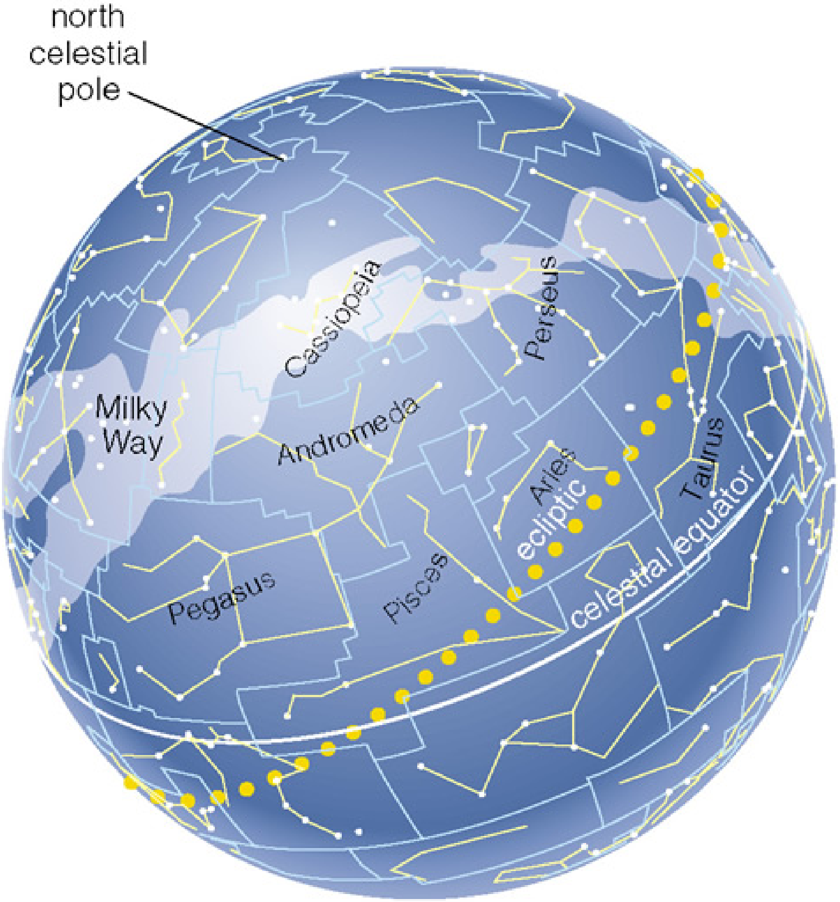
88 constellations fill the entire sky.



The Celestial Sphere



The Celestial Sphere



The Milky Way

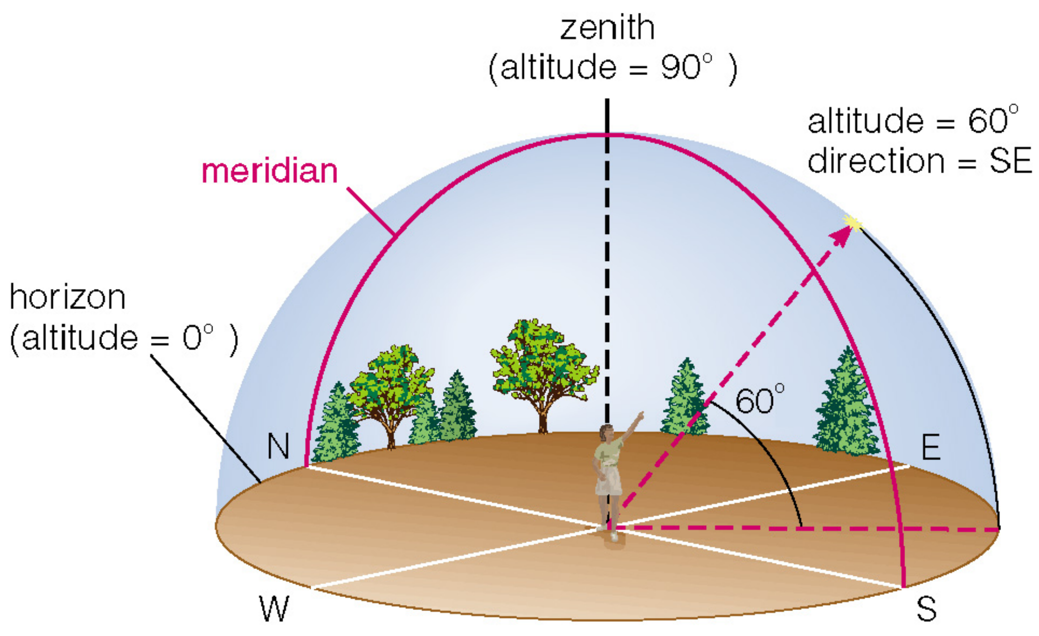
A band of light making a circle around the celestial sphere.

What is it?

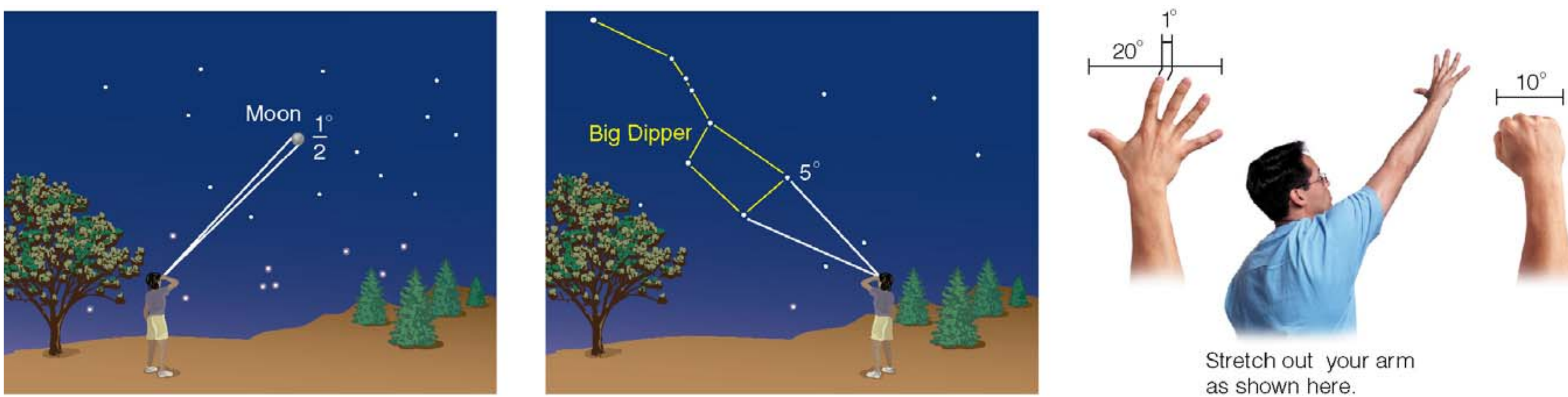
Our view into the plane of our galaxy.

How do we locate objects in the sky?

(1) Know your reference points.
(2) Locate an object by its **altitude** (above horizon) and **direction** (along horizon)

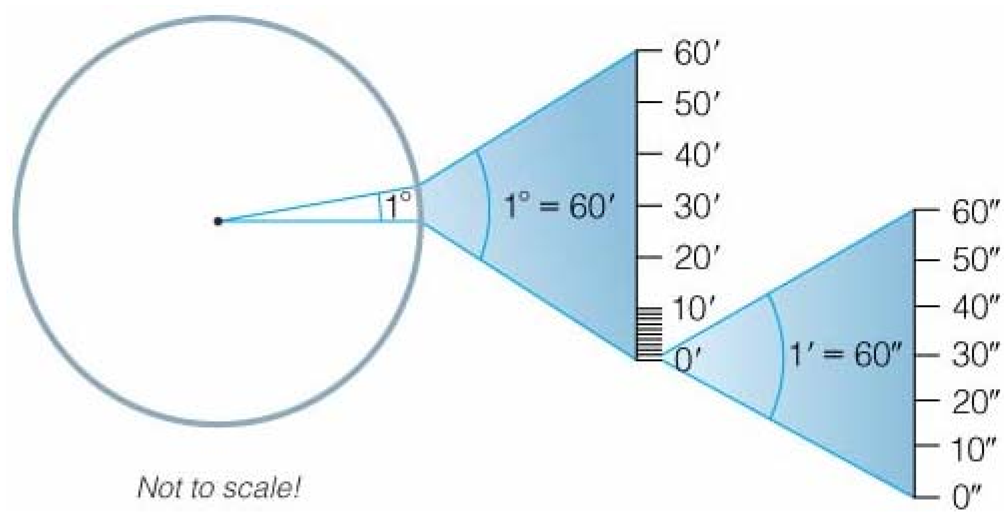


We measure the sky in *angles*...

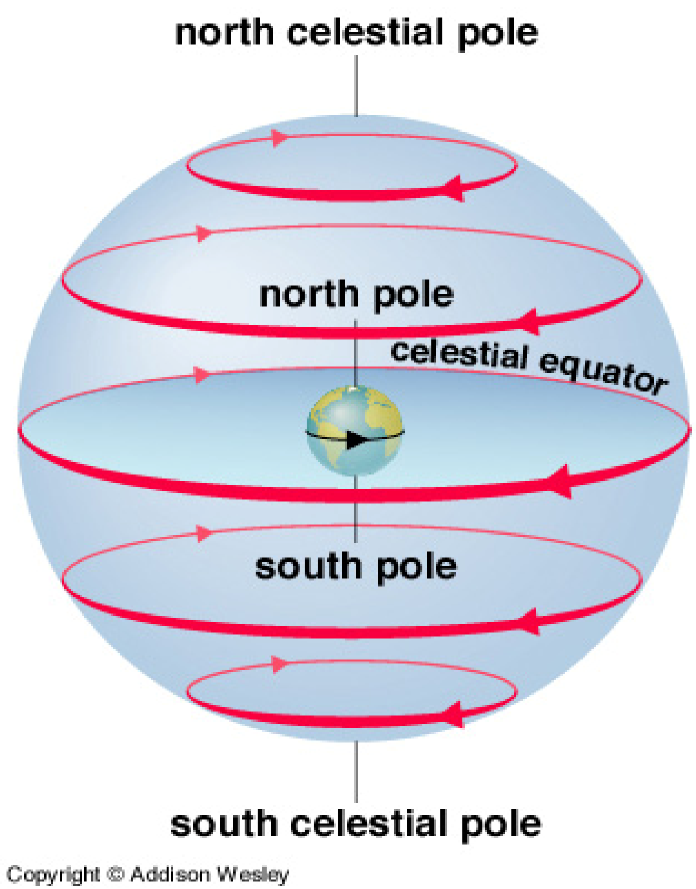


Angle measurements:

- Full circle = 360º
- 1º = 60′ (arcminutes)
- 1′ = 60″ (arcseconds)



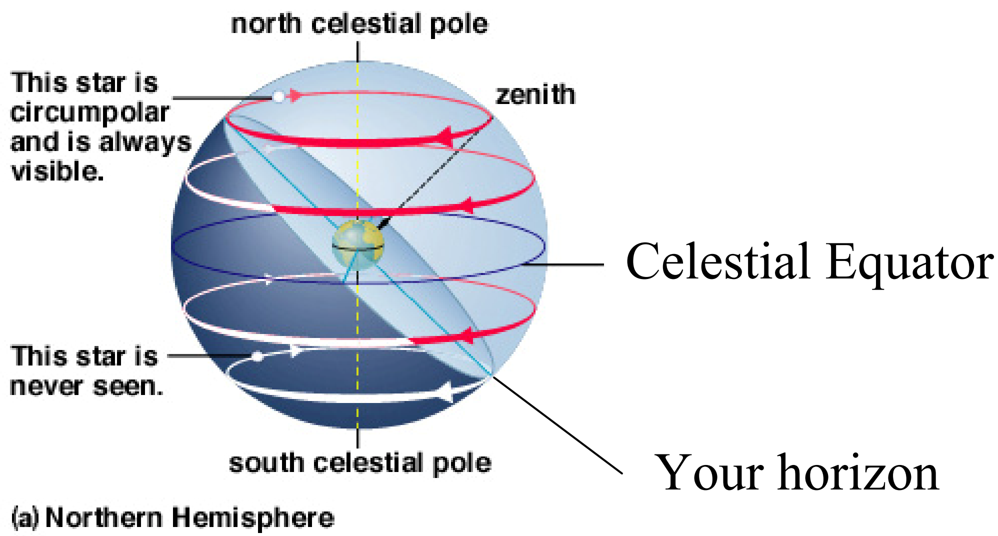
Why do stars rise and set?



Earth rotates east to west, so stars appear to circle from west to east.

Our view from Earth:

- Stars near the north celestial pole are circumpolar and never set.
- We cannot see stars near the south celestial pole.
- All other stars (and Sun, Moon, planets) rise in east and set in west.



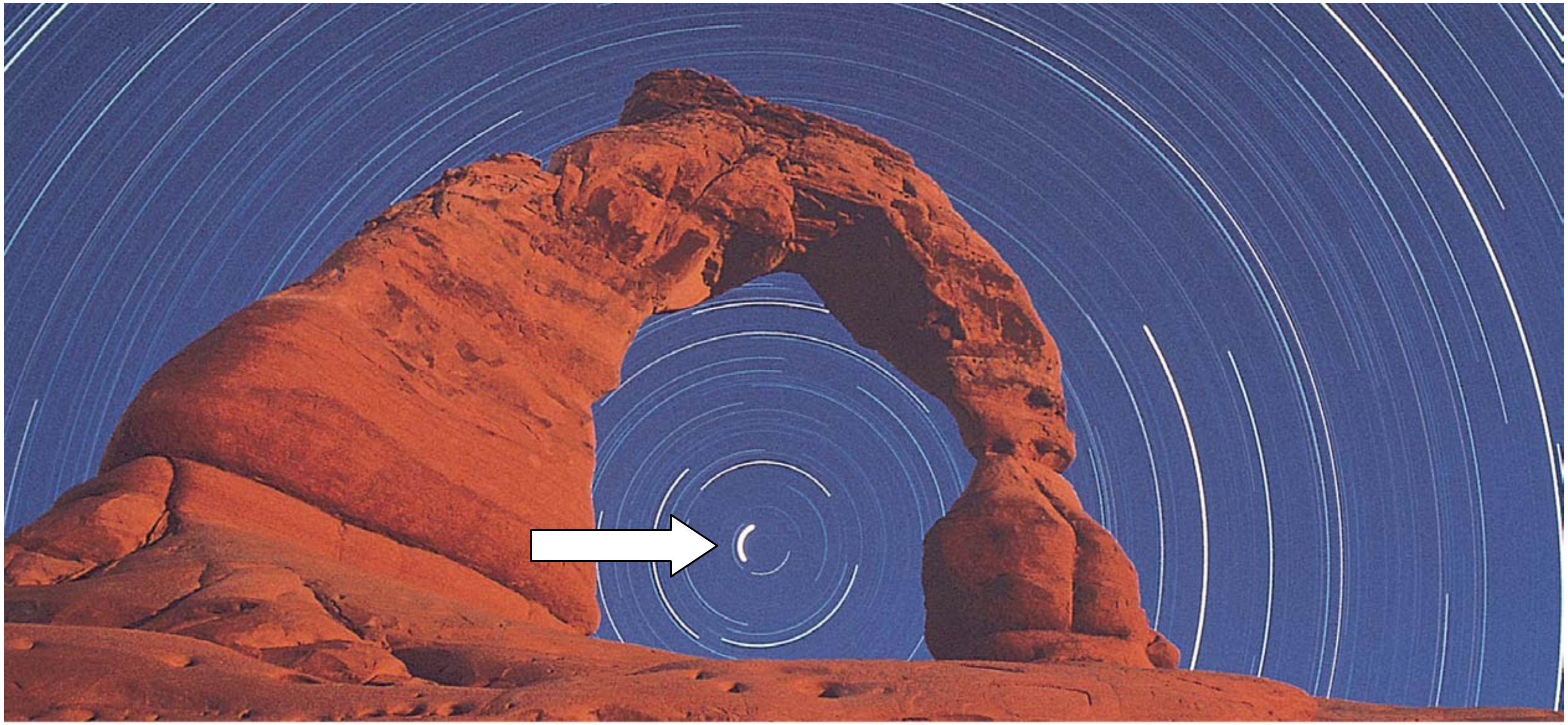
Thought Question

What is the arrow pointing to?

A. the zenith

B. the north celestial pole

C. the celestial equator



What is the arrow pointing to?

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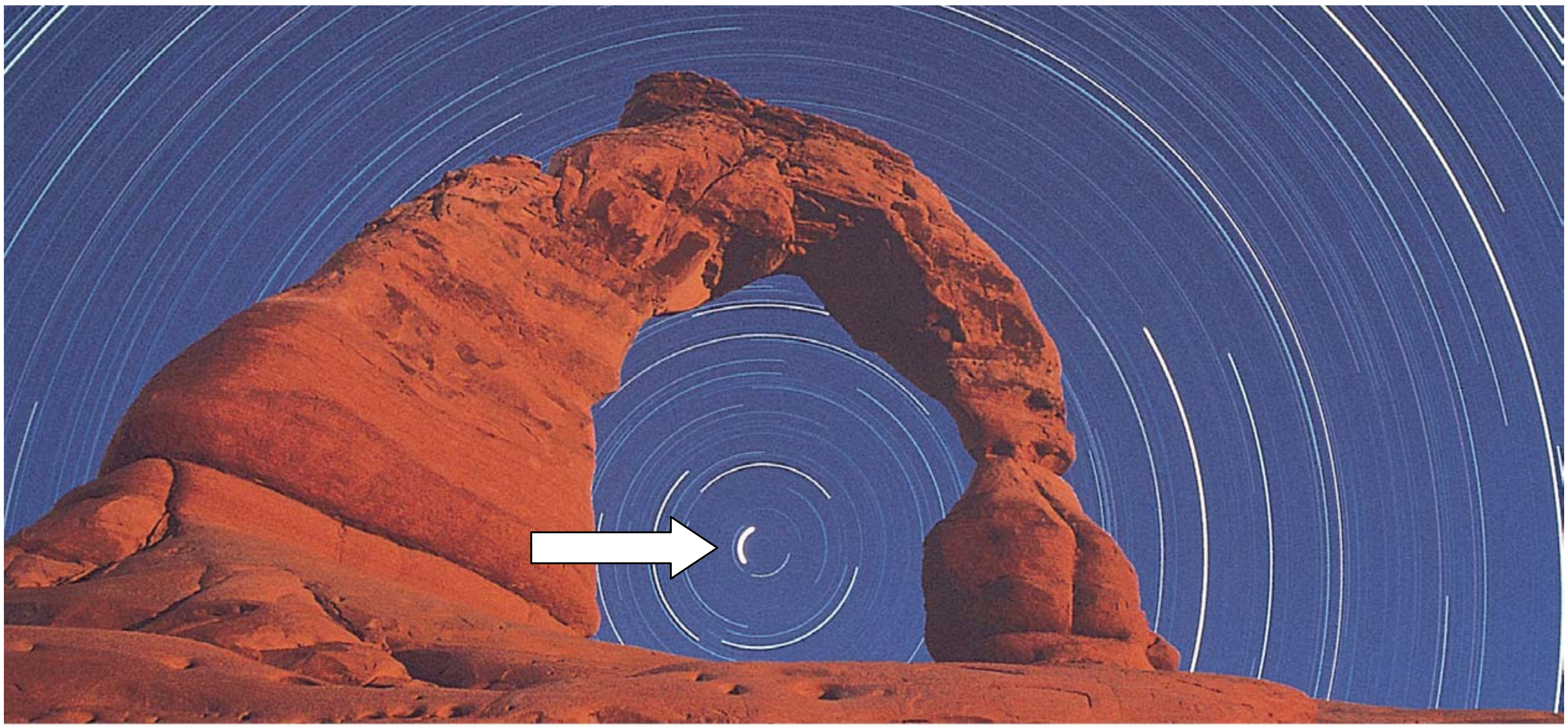
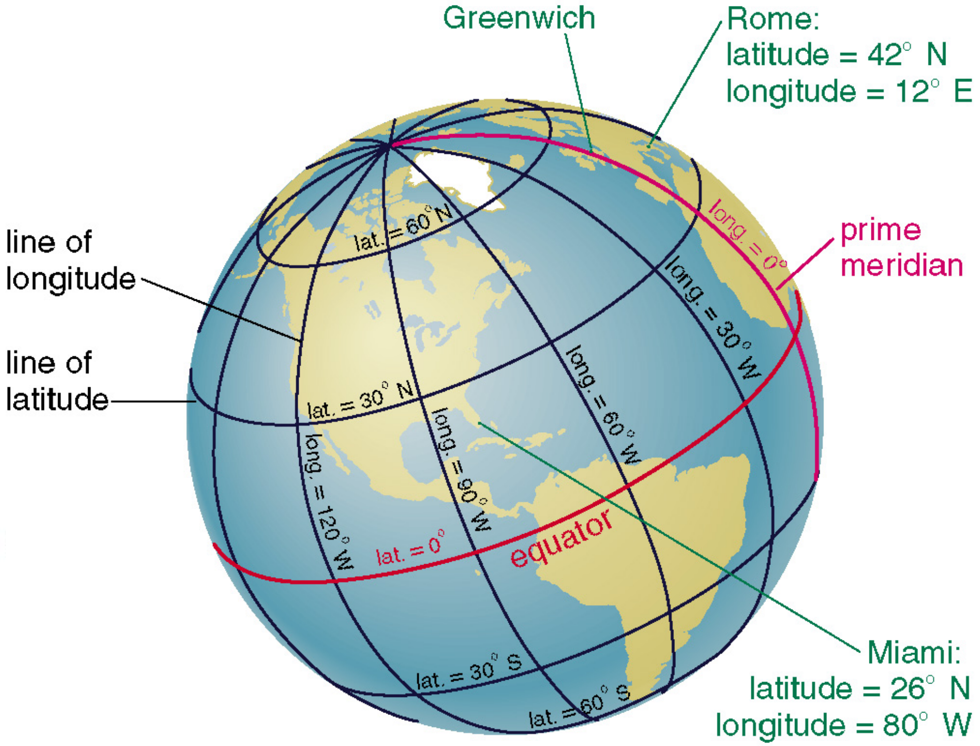


Why don't we see the same constellations throughout the year?

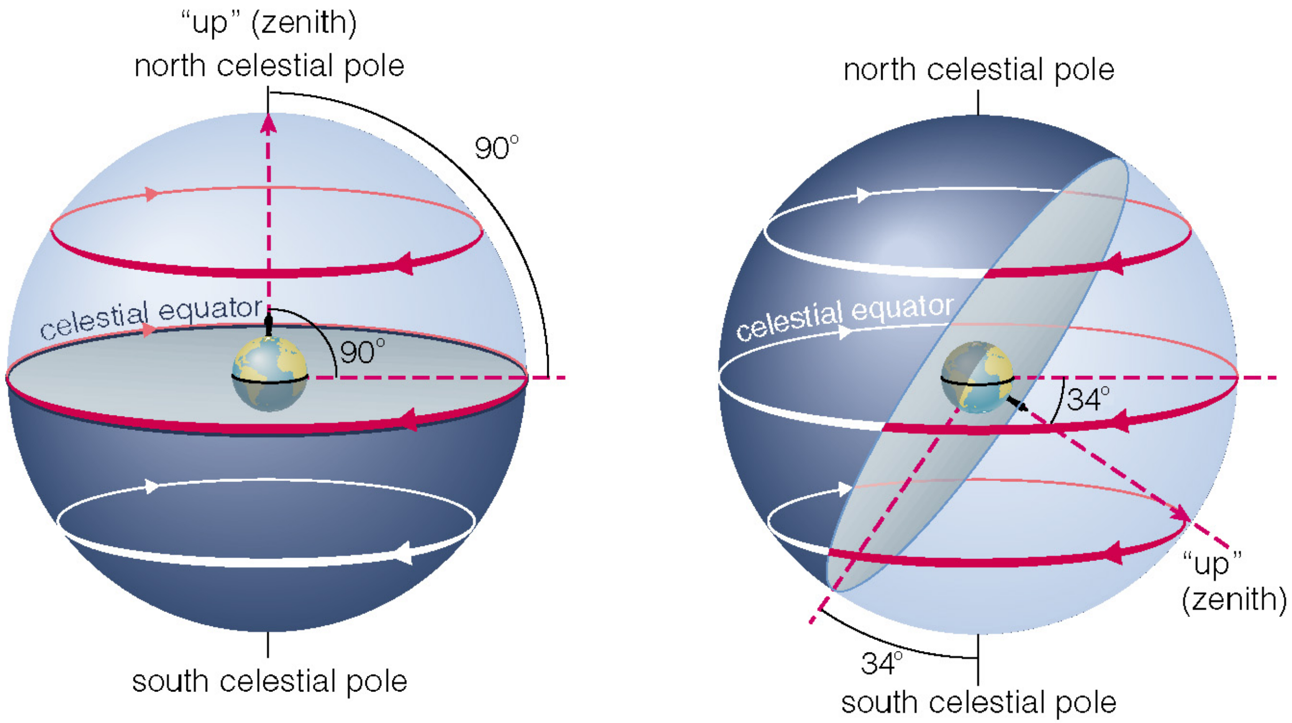
1. Depends on whether you stay home: Constellations vary with latitude.
2. Depends on time of year: Constellations vary as Earth orbits the Sun.

Review: Coordinates on the Earth

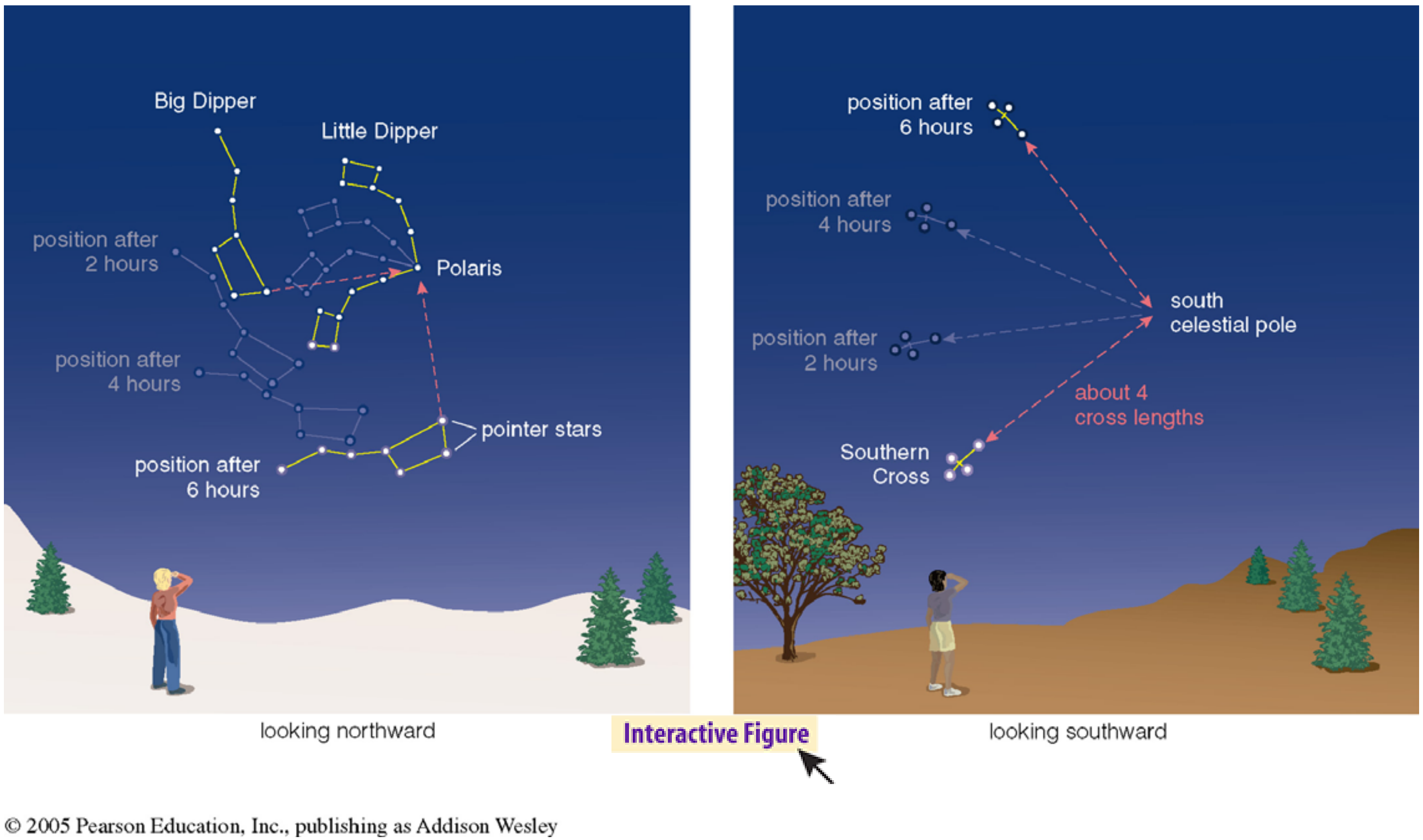
- Latitude: position north or south of equator
- Longitude: position east or west of prime meridian (runs through Greenwich, England)



The sky varies with latitude but not longitude.

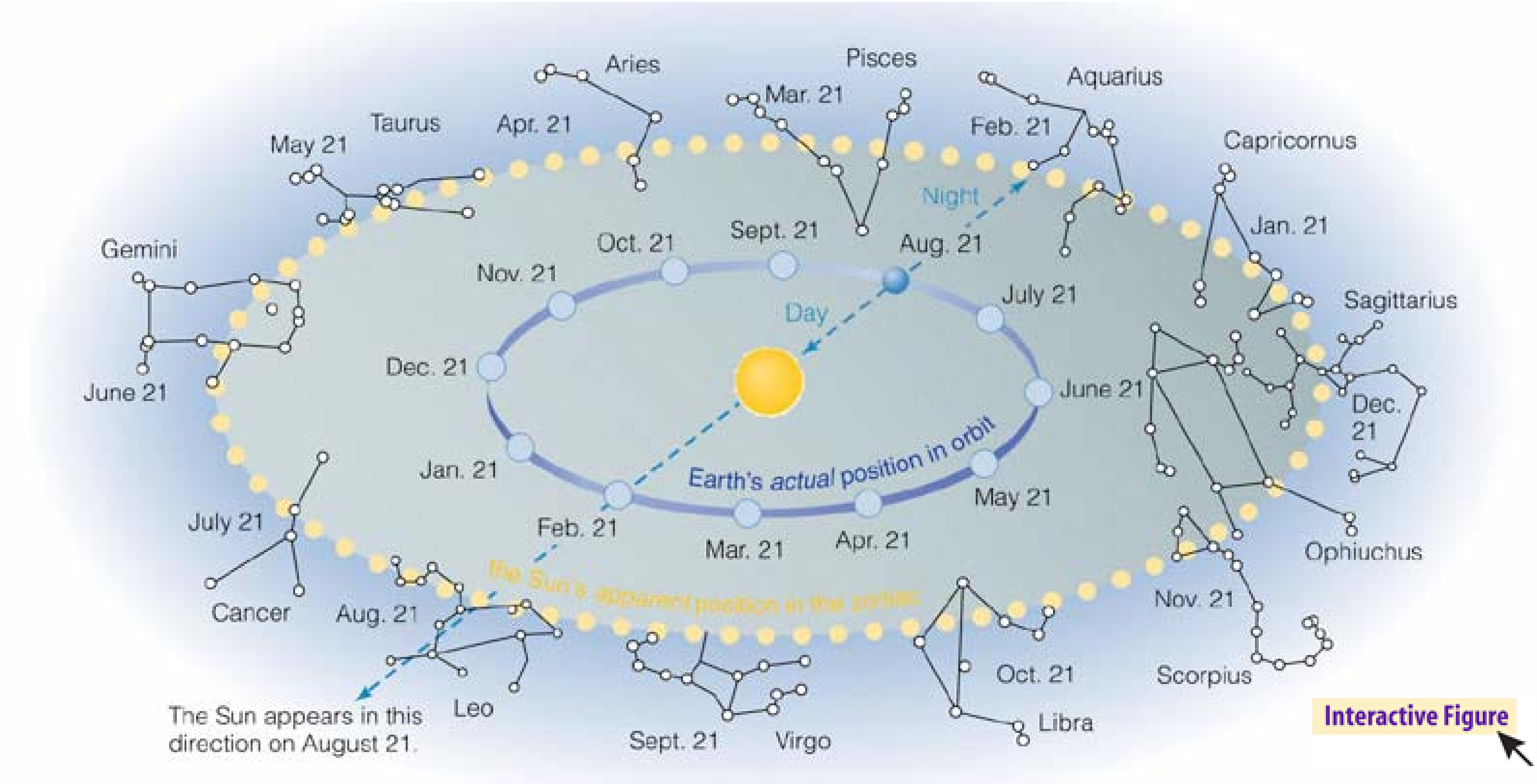


altitude of the celestial pole = your latitude



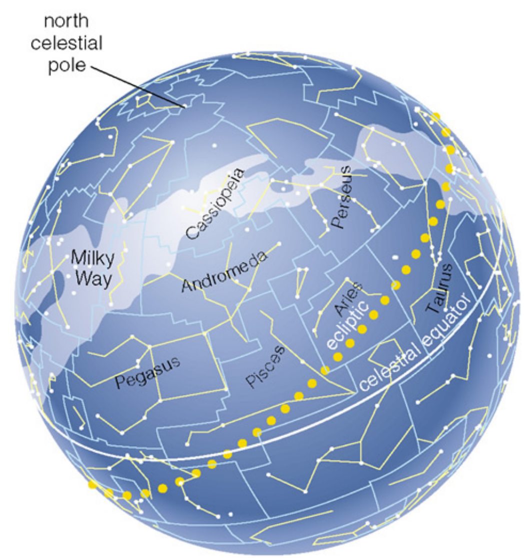
The sky varies as Earth orbits the Sun

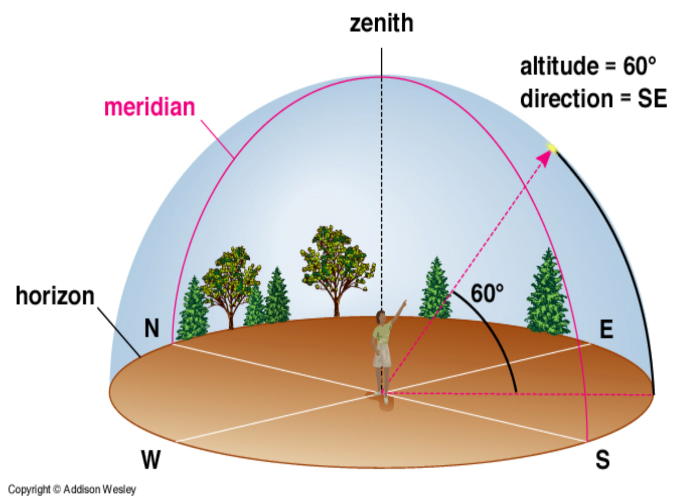
- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.
- At midnight, the stars on our meridian are opposite the Sun the



What have we learned?

- What are constellations?
  - A region of the sky; every position on the sky belongs to one of 88 constellations.
- How do we locate objects in the sky?
  - By its **altitude** above the horizon and its **direction** along the horizon.





What have we learned?

- Why do stars rise and set?
  - Because of Earth's rotation.
- Why don't we see the same constellations throughout the year?
  - The sky varies with latitude.
  - The night sky changes as Earth orbits the Sun.

2.2 The Reason for Seasons

Our goals for learning:

- What causes the seasons?
- How do we mark the progression of the seasons?
- Does the orientation of Earth's axis change with time?

Thought Question

TRUE OR FALSE? Earth is closer to the Sun in summer and farther from the Sun in winter.

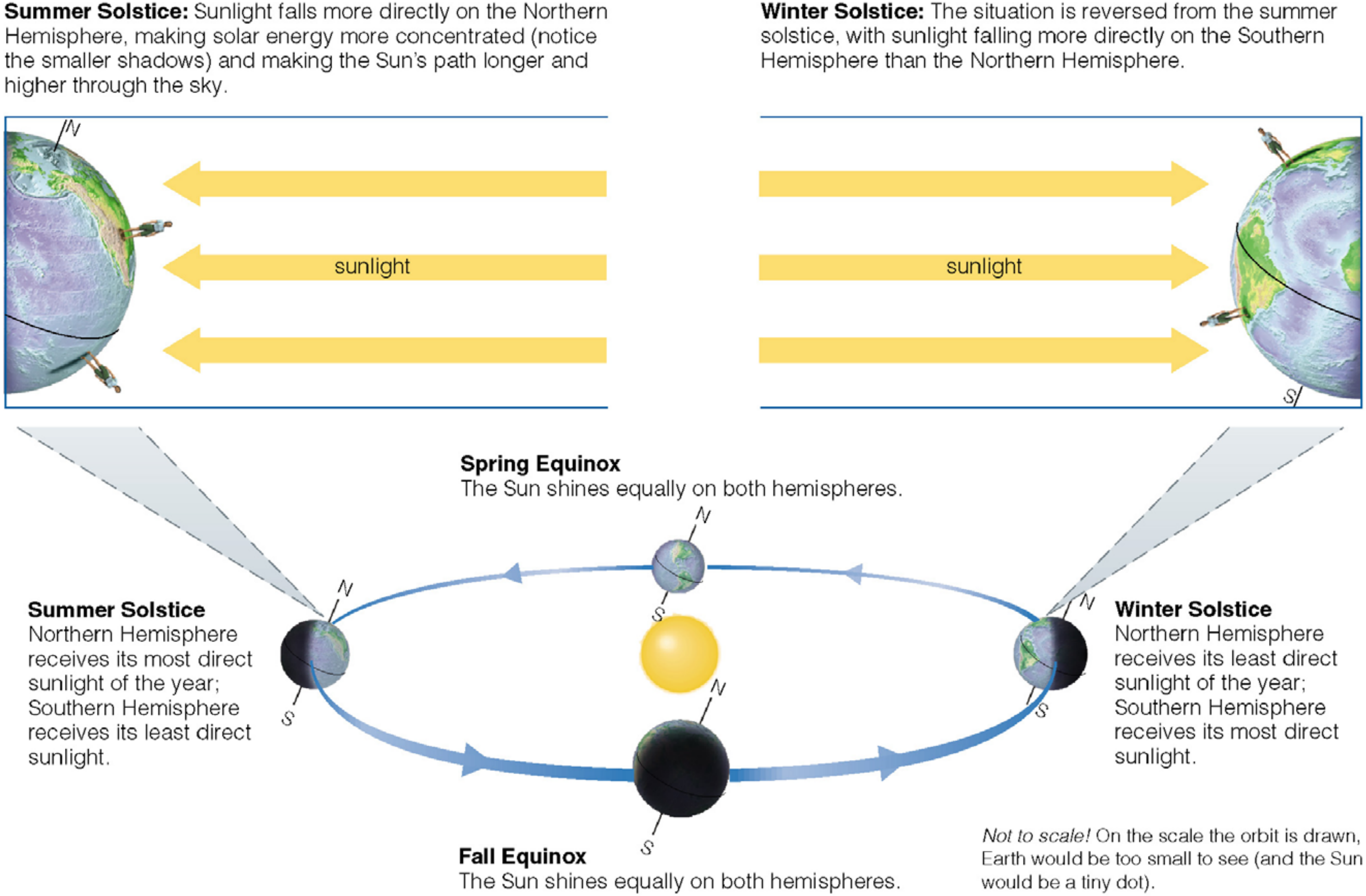
TRUE OR FALSE? Earth is closer to the Sun in summer and farther from the Sun in winter.

Hint: When it is summer in the U.S., it is winter in Australia.

TRUE OR **FALSE!** Earth is closer to the Sun in summer and farther from the Sun in winter.

- Seasons are opposite in the N and S hemispheres, so distance cannot be the reason.
- The real reason for seasons involves Earth's axis tilt.

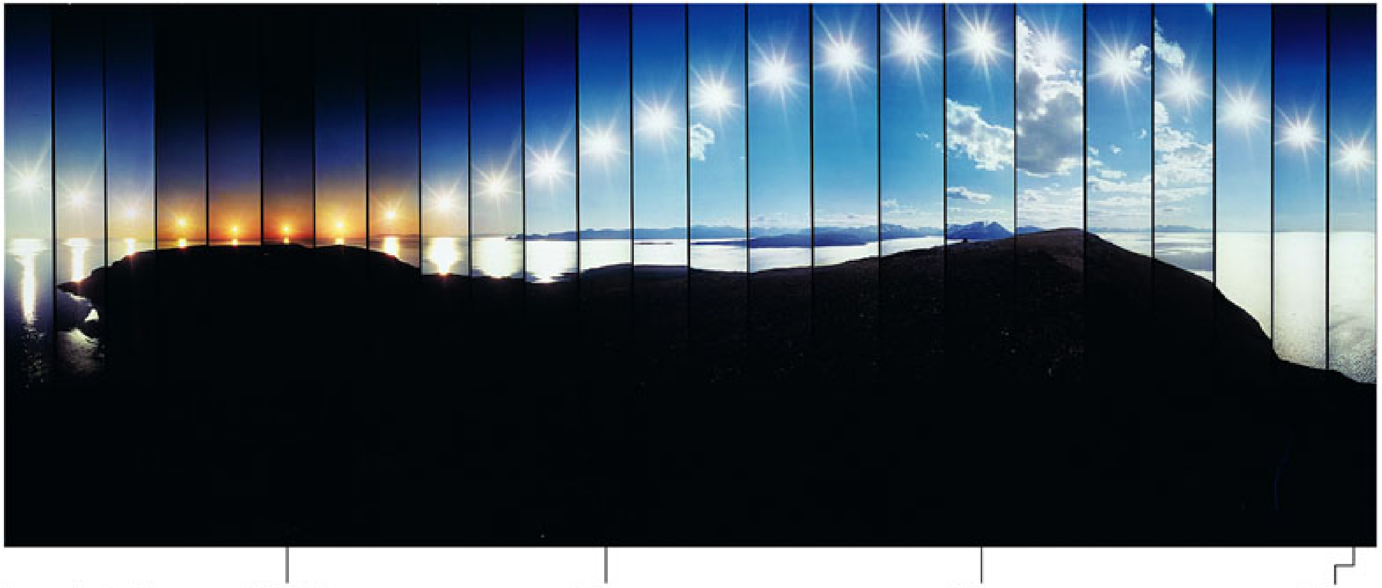
What causes the seasons?



Summary: The Real Reason for Seasons

- Earth's axis points in the same direction (to Polaris) all year round, so its orientation *relative to the Sun* changes as Earth orbits the Sun.
- Summer occurs in your hemisphere when sunlight hits it more directly; winter occurs when the sunlight is less direct.
- **AXIS TILT** is the key to the seasons; without it, we would not have seasons on Earth.

Seasonal changes are more extreme at high latitudes



Path of the Sun on the summer solstice at the Arctic Circle

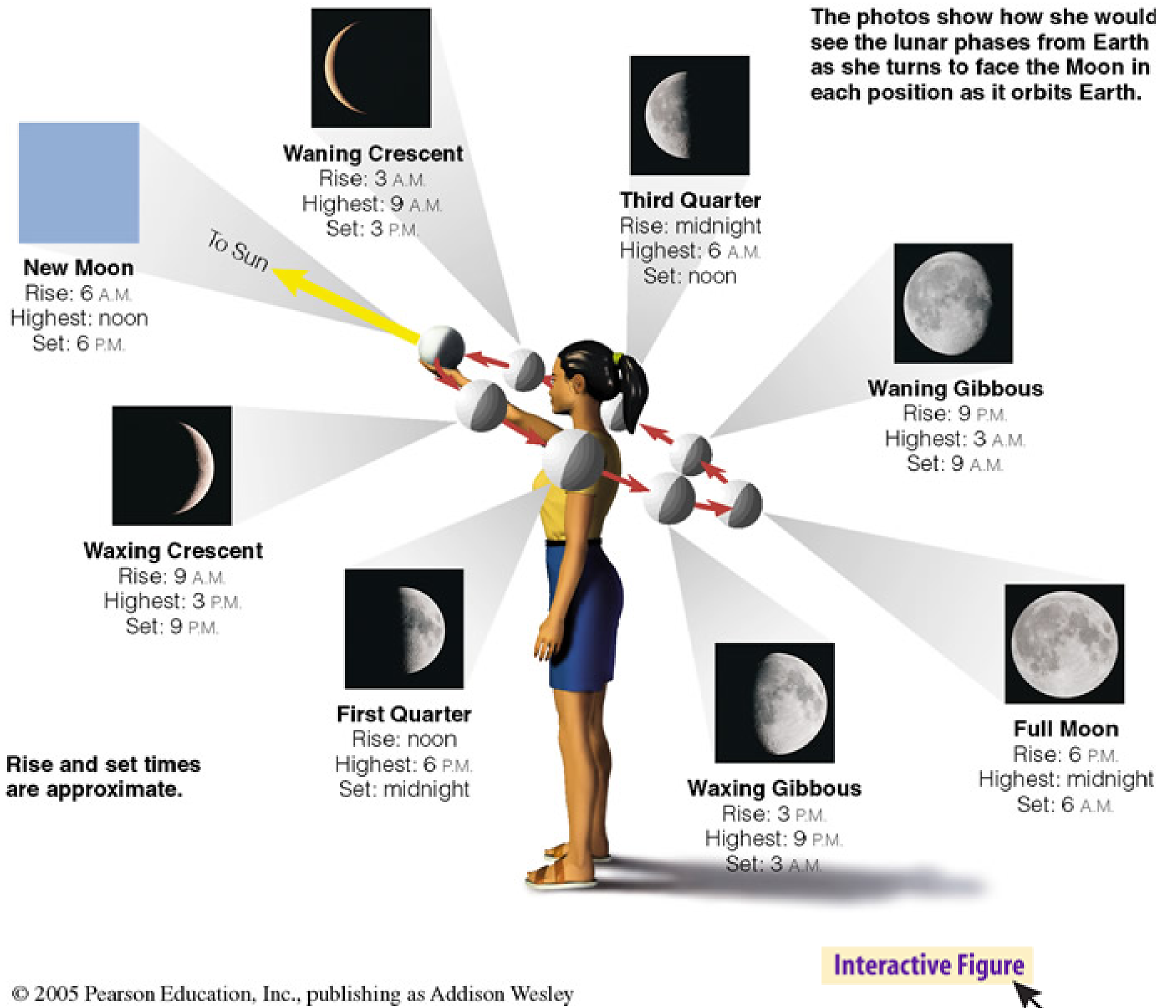
2.3 The Moon, Our Constant Companion

Our goals for learning:

- Why do we see phases of the Moon?
- What causes eclipses?

Why do we see phases of the Moon?

- Half the Moon illuminated by Sun and half dark
- We see some combination of the bright and dark faces



Phases of the Moon: 29.5-day cycle

- new
- crescent
- first quarter
- gibbous
- full
- gibbous
- last quarter
- crescent

waxing

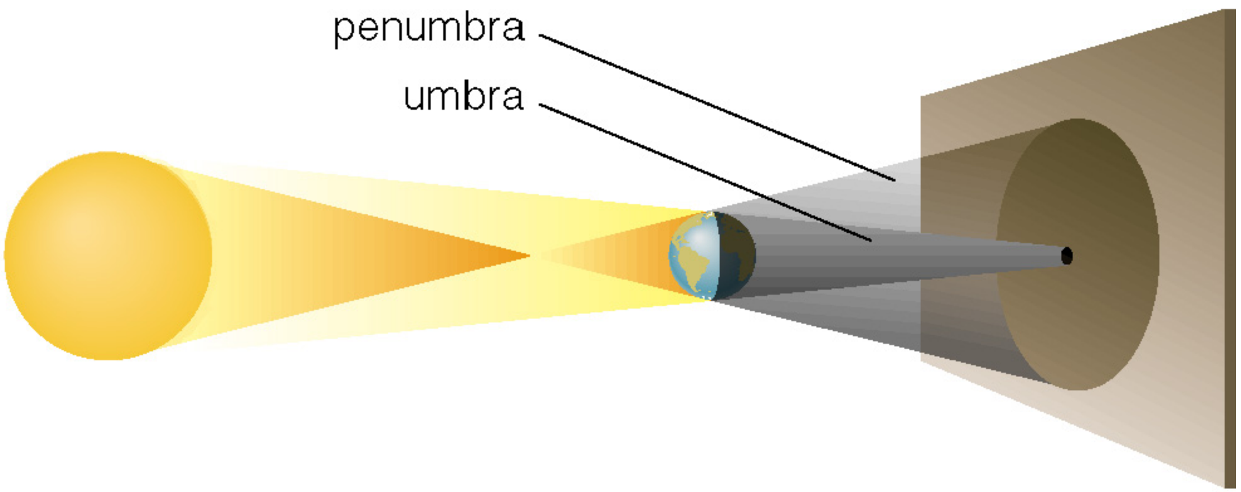
- Moon visible in afternoon/evening.
- Gets "fuller" and rises later each day.

waning

- Moon visible in late night/morning.
- Gets "less" and sets later each day.

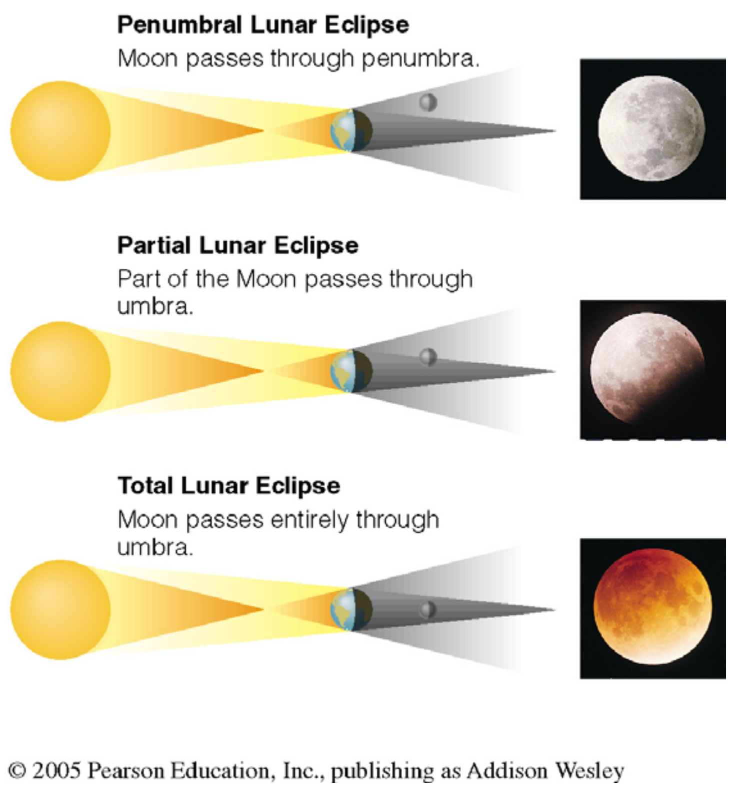
What causes eclipses?

- The Earth and Moon cast shadows.
- When either passes through the other's shadow, we have an **eclipse**.



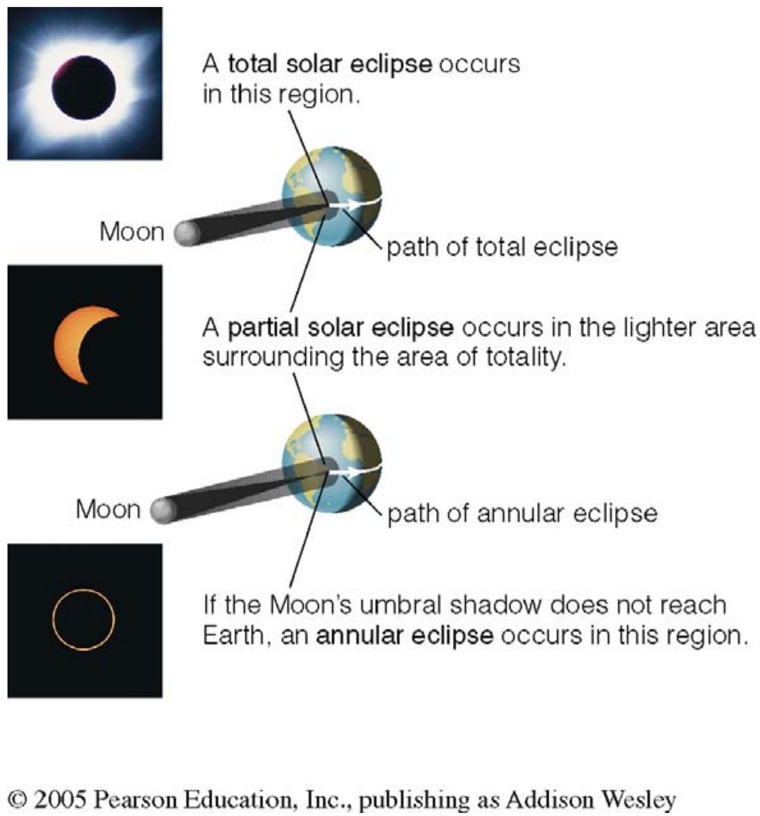
When can eclipses occur?

- **Lunar eclipses** can occur only at *full moon*.
- Lunar eclipses can be **penumbral**, **partial**, or **total**.



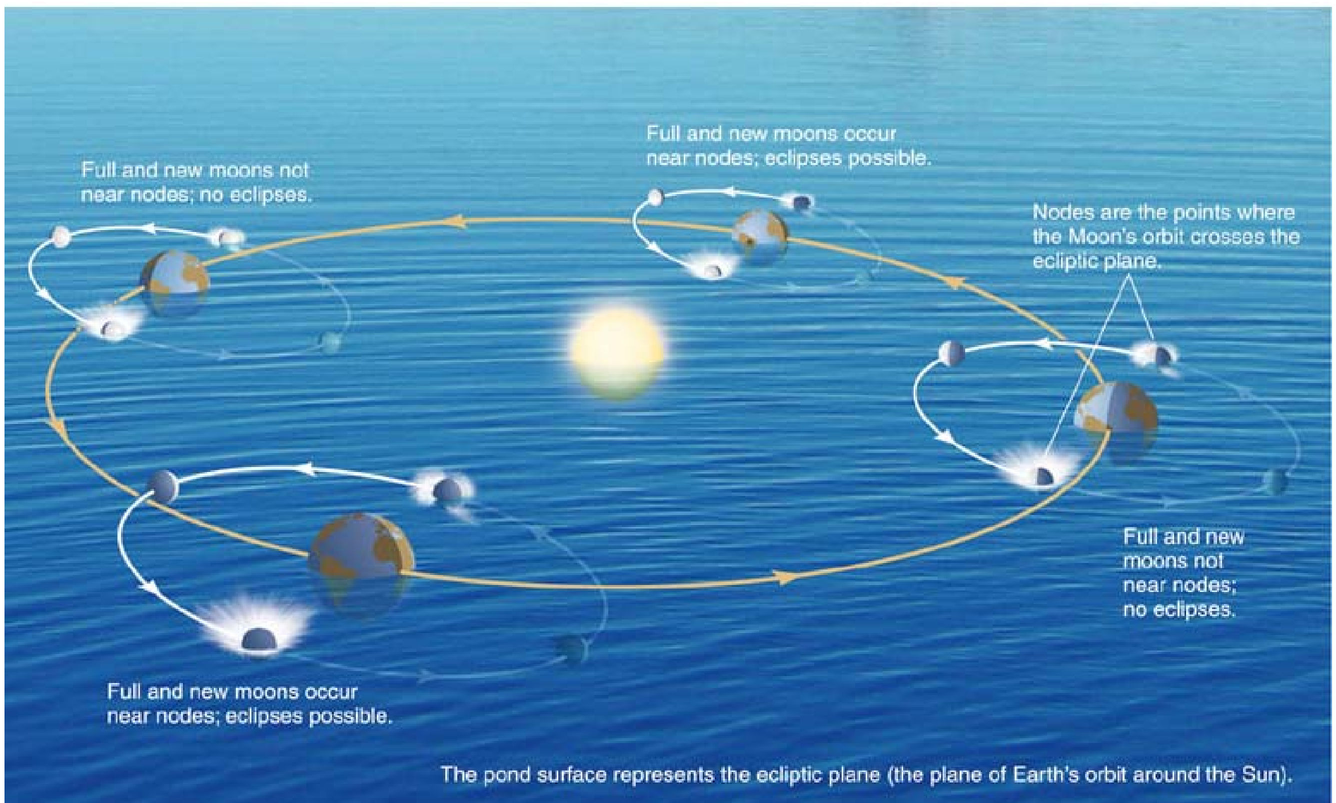
When can eclipses occur?

- **Solar eclipses** can occur only at *new moon*.
- Solar eclipses can be **partial**, **total,** or **annular**.



Why don't we have an eclipse at every new and full moon?

- The Moon's orbit is tilted 5° to ecliptic plane…
- So we have about two **eclipse seasons** each year, with a lunar eclipse at new moon and solar eclipse at full moon.



Summary: Two conditions must be met to have an eclipse:

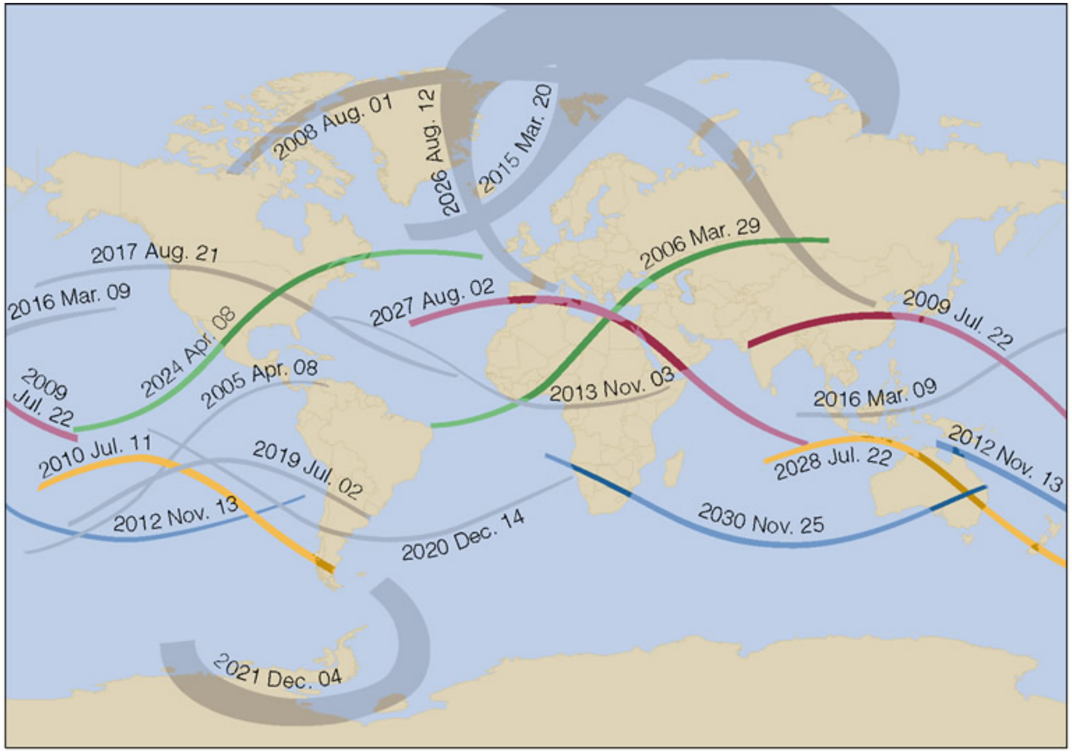
1. It must be full moon (for a lunar eclipse) or new moon (for a solar eclipse).

   AND

2. The Moon must be at or near one of the two points in its orbit where it crosses the ecliptic plane (its nodes).

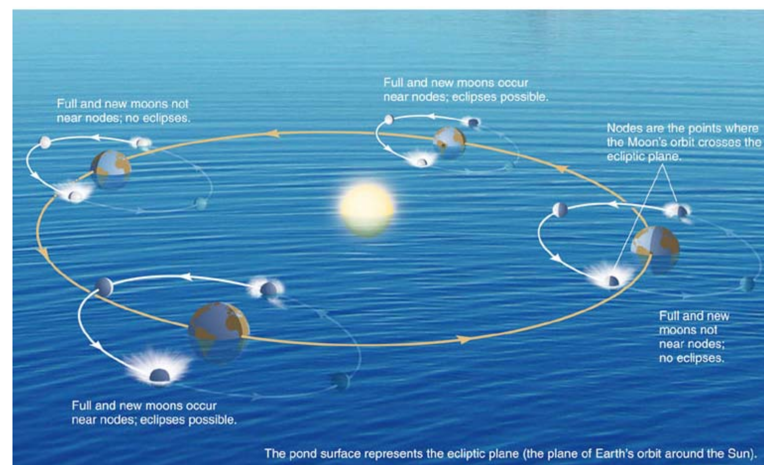
Predicting Eclipses

- Eclipses recur with the 18 yr, 11 1/3 day **saros cycle**, but type (e.g., partial, total) and location may vary.



What have we learned?

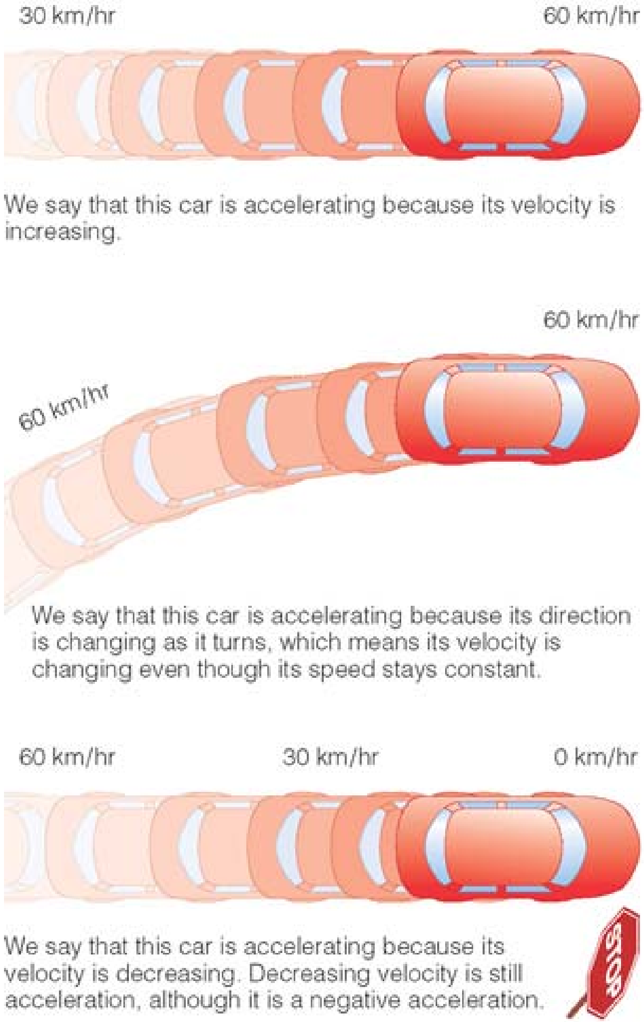
- Why do we see phases of the Moon?
  - Half the Moon is lit by the Sun; half is in shadow.
  - The appearance of the Moon to us is determined by the Sun, Earth, and Moon positions.
- What causes eclipses?
  - Lunar eclipse: Earth's shadow on the Moon. Can be penumbral, partial, or total.
  - Solar eclipse: the Moon's shadow on Earth. Can be partial, total, or annular.
  - Tilt of Moon's orbit means eclipses occur during two periods each year.
  - Eclipses recur with the 18 yr, 11 1/3 day saros cycle



4.1 Describing Motion

- Our goals for learning:
- How do we describe motion?
- How is mass different from weight?

How do we describe motion?



Precise definitions to describe motion:

- **speed**: rate at which object moves

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \left(\text{units of } \frac{\text{m}}{\text{s}}\right)$$

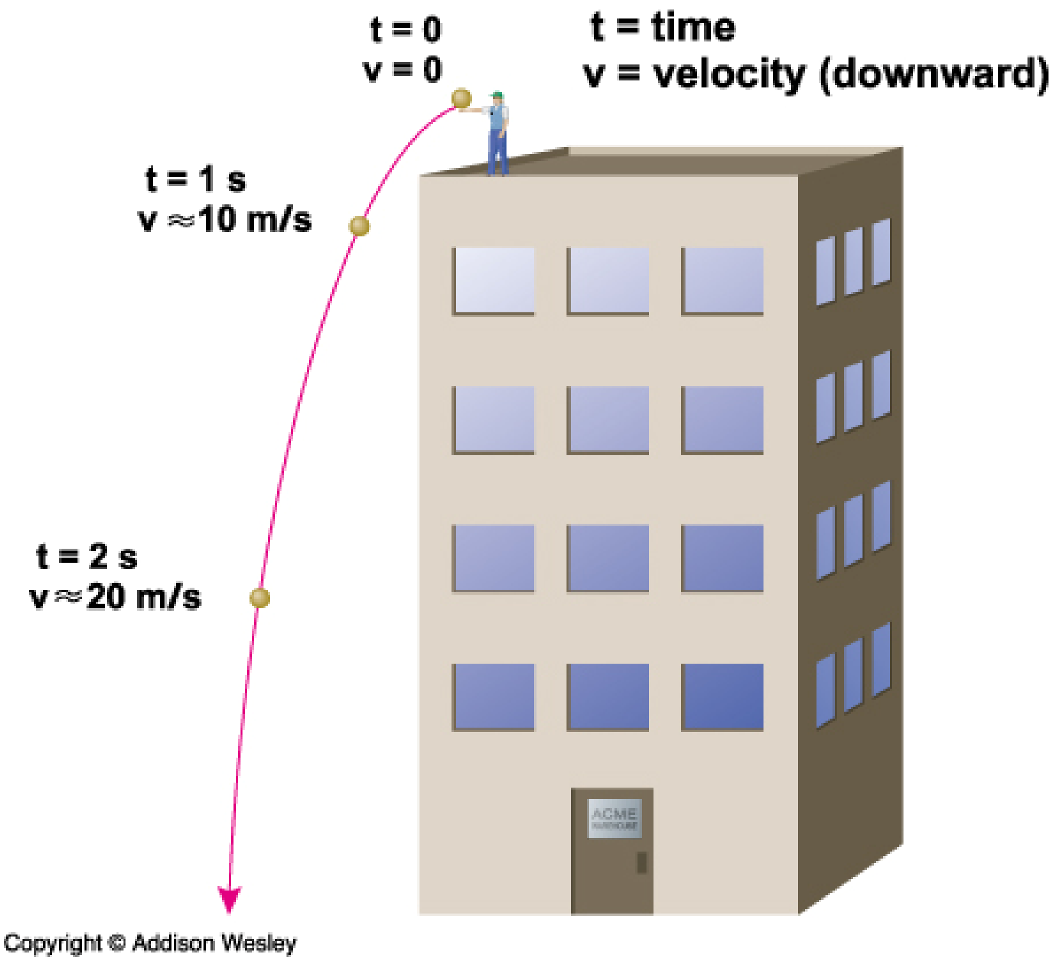
example: speed of 10 m/s

- **velocity**: speed and direction
  example: 10 m/s, due east

- **acceleration**: any change in velocity
  units of speed/time (m/s^2)

The Acceleration of Gravity

- All falling objects accelerate at the same rate (not counting friction of air resistance).
- On Earth, $g \approx 10$ m/s^2: speed increases 10 m/s with each second of falling.



The Acceleration of Gravity (*g*)

- Galileo showed that *g* is the *same* for all falling objects, regardless of their mass.

Apollo 15 demonstration

Momentum and Force

- Momentum = mass × velocity
- A **net force** changes momentum, which generally means an acceleration (change in velocity)

Thought Question:
Is there a net force? Y/N

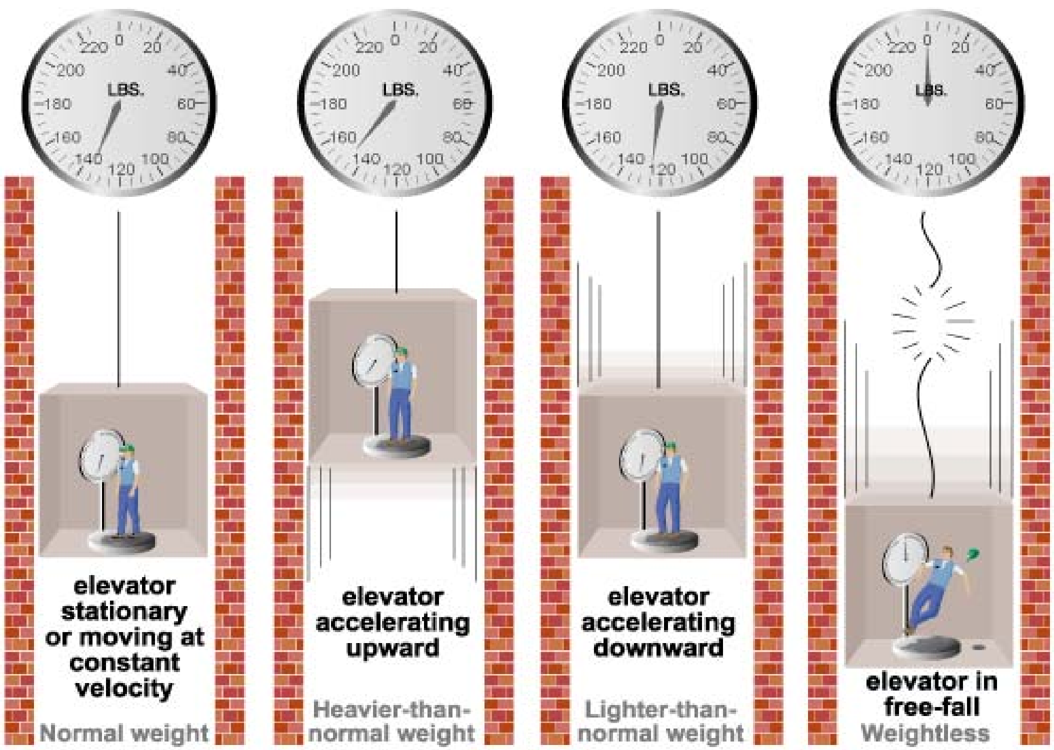
1. A car coming to a stop.
2. A bus speeding up.
3. An elevator moving up at constant speed.
4. A bicycle going around a curve.
5. A moon orbiting Jupiter.

Is there a net force? Y/N

1. A car coming to a stop. Y
2. A bus speeding up. Y
3. An elevator moving at constant speed. N
4. A bicycle going around a curve. Y
5. A moon orbiting Jupiter. Y

How is mass different from weight?

- **mass** – the amount of matter in an object
- **weight** – the *force* that acts upon an object



You are weightless in free-fall!

Interactive Figure

Thought Question
On the Moon:

A. My weight is the same, my mass is less.
B. My weight is less, my mass is the same.
C. My weight is more, my mass is the same.
D. My weight is more, my mass is less.

On the Moon…

A. My weight is the same, my mass is less.
B. My weight is less, my mass is the same.
C. My weight is more, my mass is the same.
D. My weight is more, my mass is less.

Why are astronauts weightless in space?

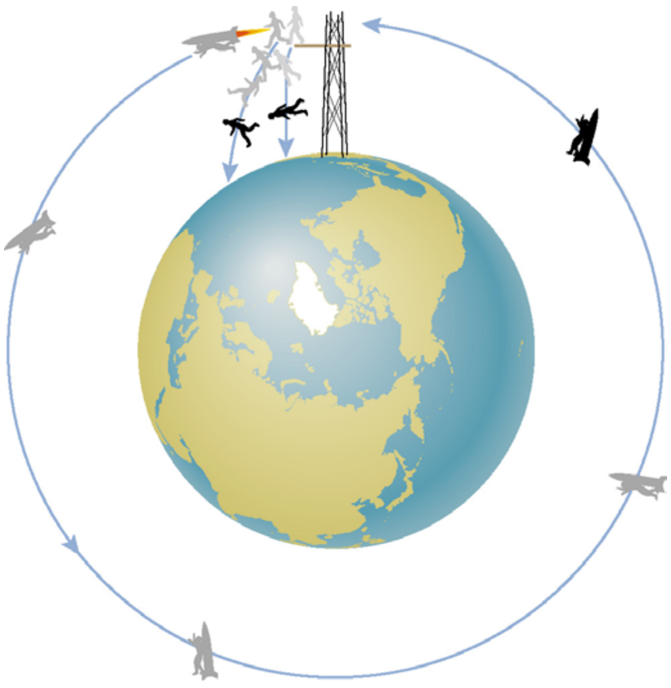
- There IS gravity in space…
- weightlessness is due to a constant state of free-fall:

What have we learned?

- How do we describe motion?
  - Speed = distance/time
  - Speed + direction => **velocity (v)**
  - Change in velocity => **acceleration (a)**
  - **Momentum** = mass × velocity
  - **Force** causes a change in momentum, which means acceleration.

What have we learned?

- How is mass different from weight?
  - Mass = quantity of matter
  - Weight = force acting on mass
  - Objects are weightless when in free-fall



4.4 The Force of Gravity

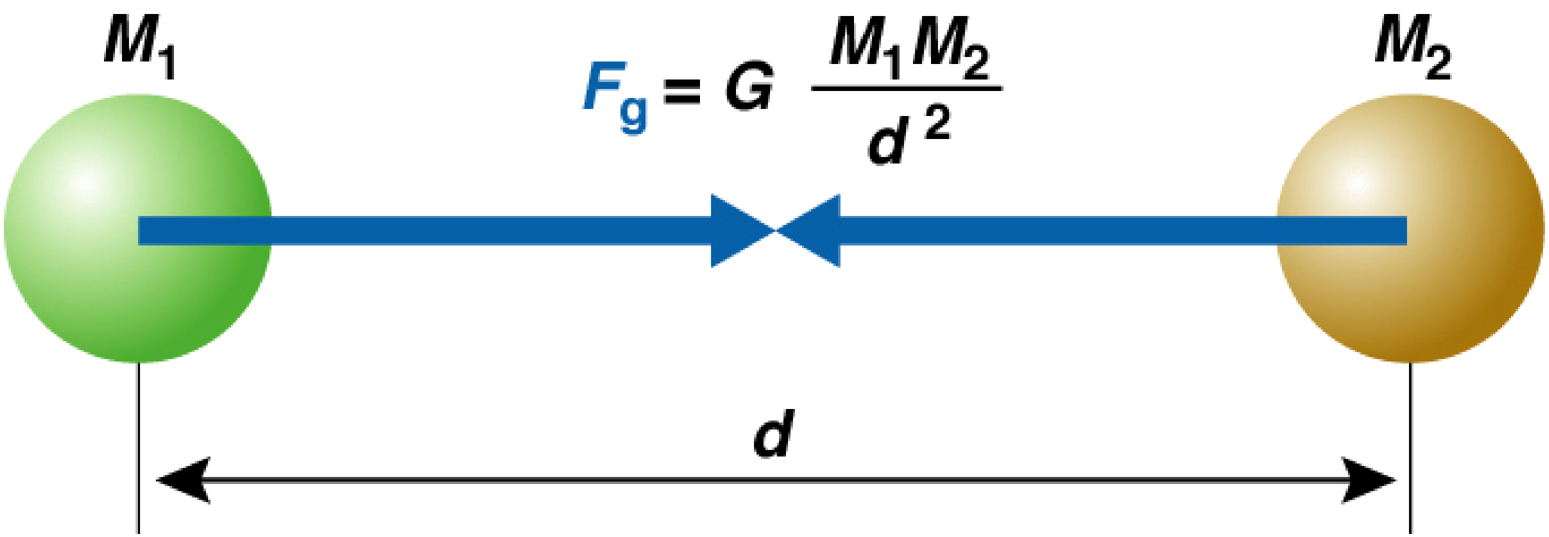
Our goals for learning:

- What determines the strength of gravity?
- How does Newton's law of gravity extend Kepler's laws?
- How do gravity and energy together allow us to understand orbits?
- How does gravity cause tides?

What determines the strength of gravity?

The **Universal Law of Gravitation**

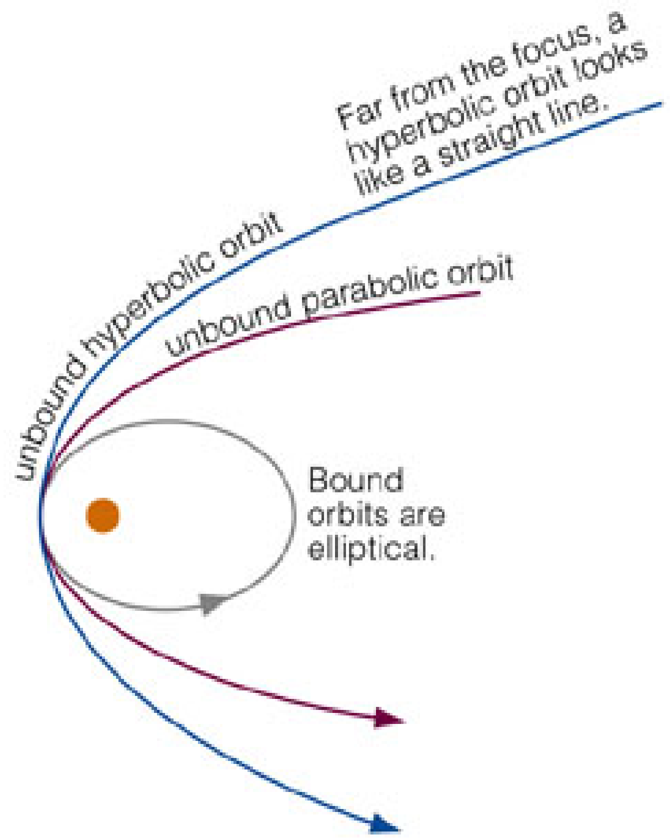
1. Every mass attracts every other mass.
2. Attraction is *directly* proportional to the product of their masses.
3. Attraction is *inversely* proportional to the *square* of the distance between their centers..



How does Newton's law of gravity extend Kepler's laws?

- Kepler's first two laws apply to all orbiting objects, not just planets

- Ellipses are not the only orbital paths. Orbits can be:
  - bound (ellipses)
  - unbound
    - Parabola
    - hyperbola



- Newton generalized Kepler’s Third Law:

Newton’s version of Kepler’s Third Law:
If a small object orbits a larger one and you measure the orbiting object’s
orbital period AND *average orbital distance*
THEN you can calculate the mass of the larger object.

Examples:

- Calculate mass of Sun from Earth’s orbital period (1 year) and average distance (1 AU).
- Calculate mass of Earth from orbital period and distance of a satellite.
- Calculate mass of Jupiter from orbital period and distance of one of its moons.

Newton's version of Kepler's Third Law

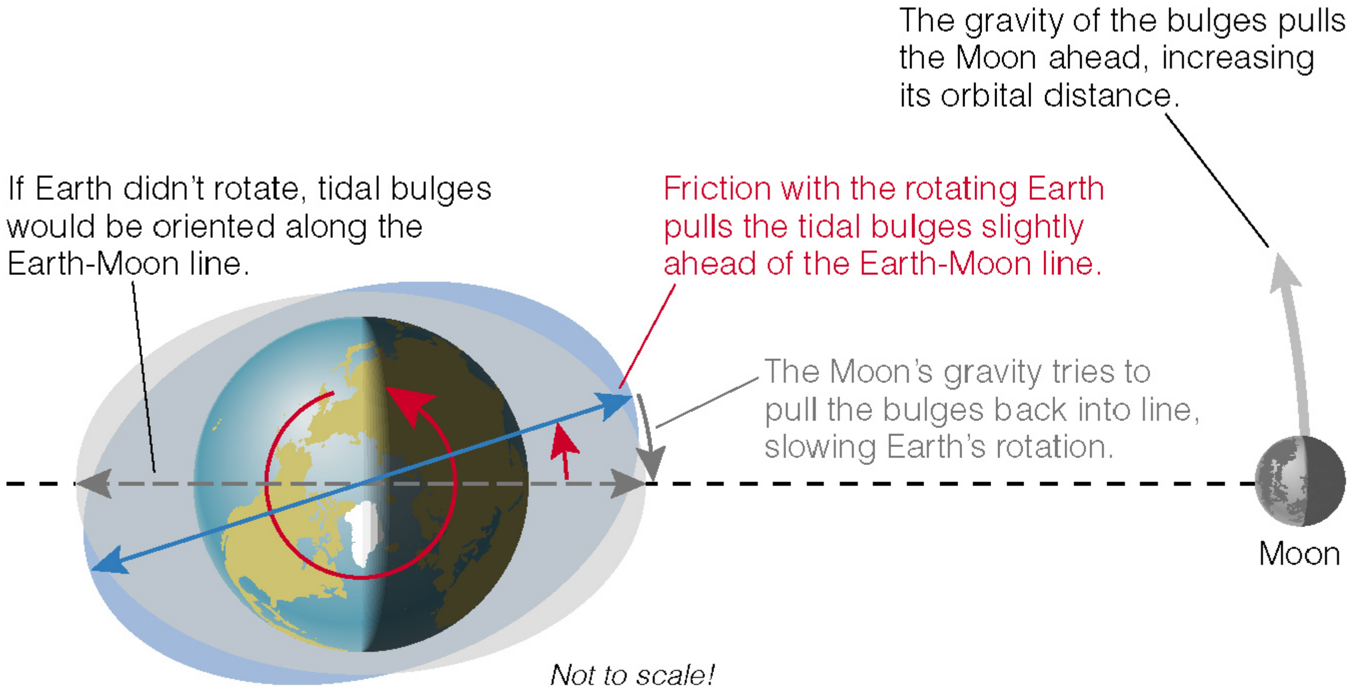
$$p^2 = \frac{4\pi^2}{G(M_1+M_2)} a^3$$

p = orbital period

a=average orbital distance (between centers)

$(M_1 + M_2)$ = sum of object masses

Tidal friction…



- Tidal friction gradually slows Earth rotation (and makes Moon get farther from Earth).
- Moon once orbited faster (or slower); tidal friction caused it to "lock" in synchronous rotation.