

2.2 The Reason for Seasons

- Our goals for learning:
 - **What causes the seasons?**
 - **How 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.

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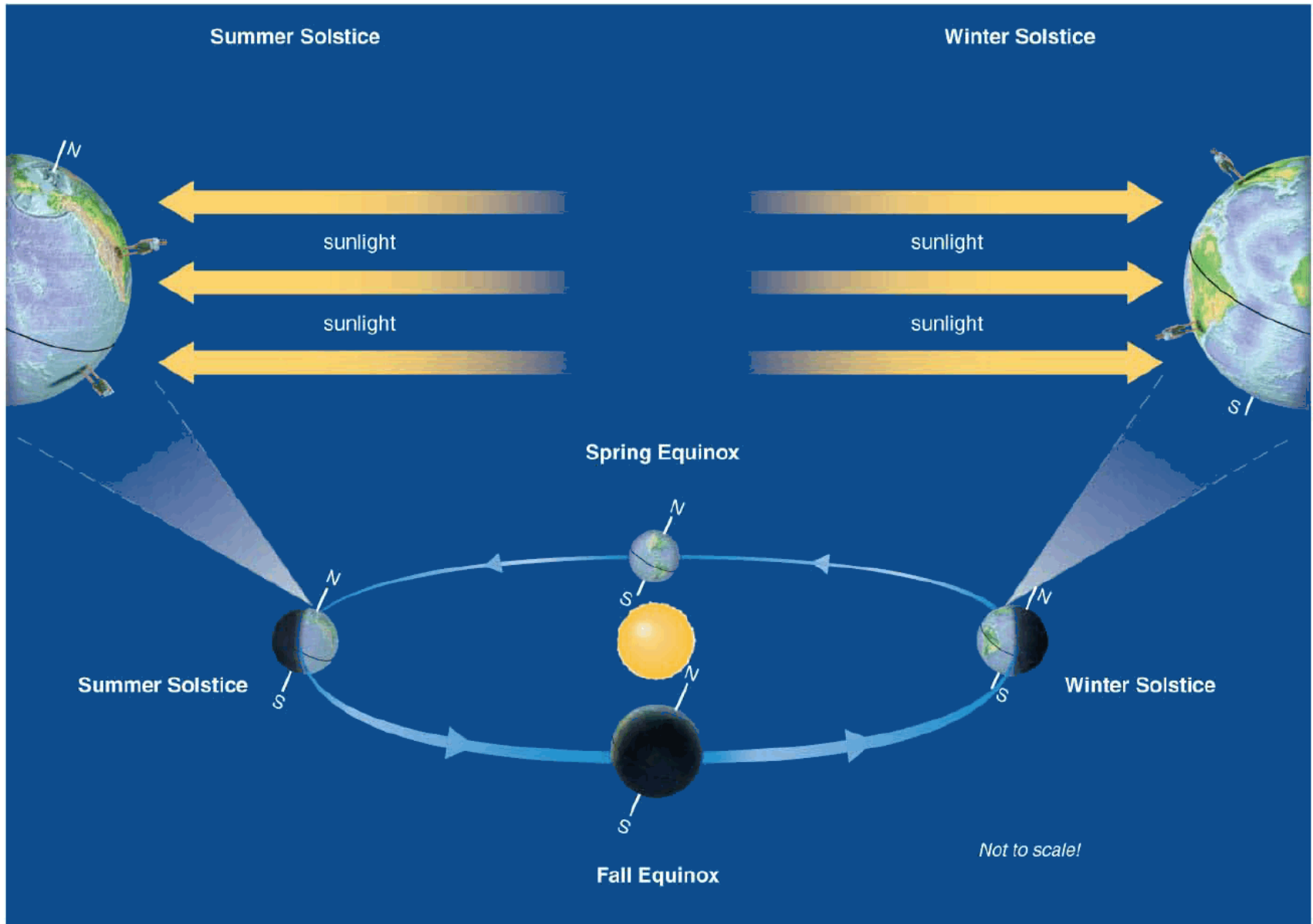
Hint: When it is summer in America, it is winter in Australia.

Thought Question

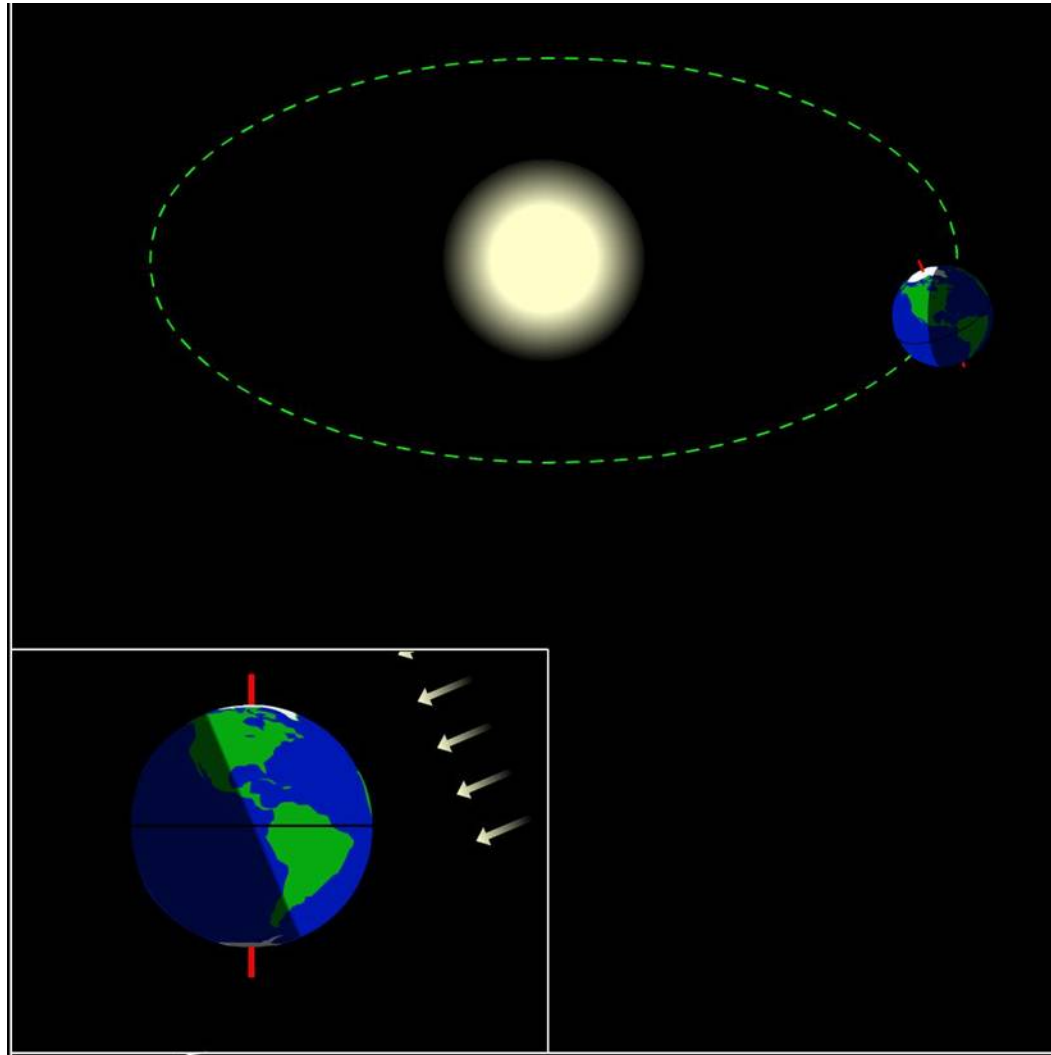
TRUE OR **FALSE!** Earth is closer to the Sun in summer and farther from the Sun in winter.

- 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?

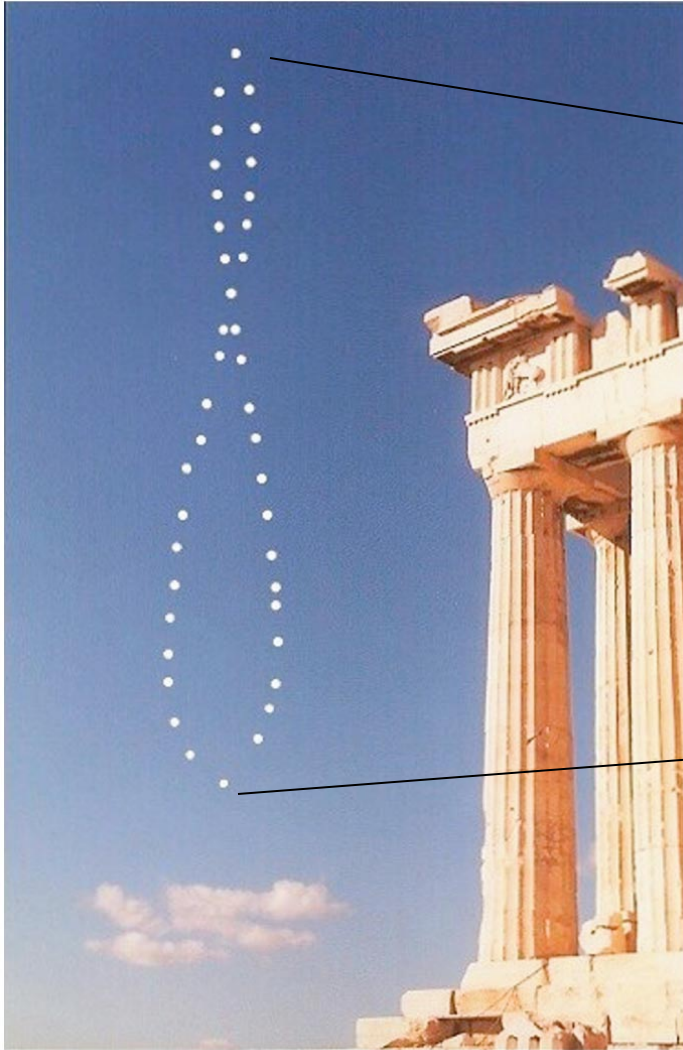


Axis tilt changes directness of sunlight during the year.



Interactive Figure

Sun's altitude also changes with seasons



Sun's position at noon in summer: Higher altitude means more direct sunlight.

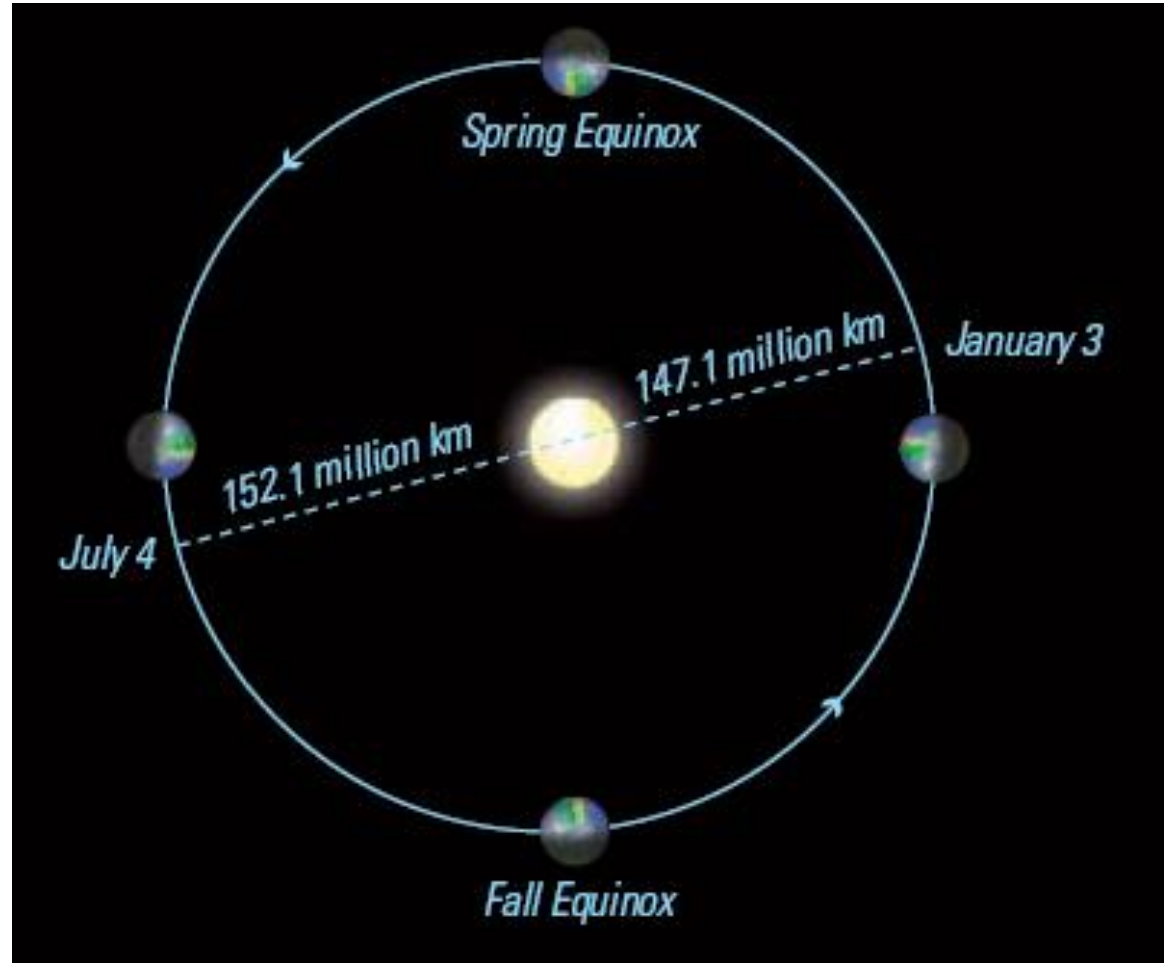
Sun's position at noon in winter: Lower altitude means less direct sunlight.

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.

Why *doesn't* distance matter?

Variation of Earth–Sun distance is small — about 3%; this small variation is overwhelmed by the effects of axis tilt.



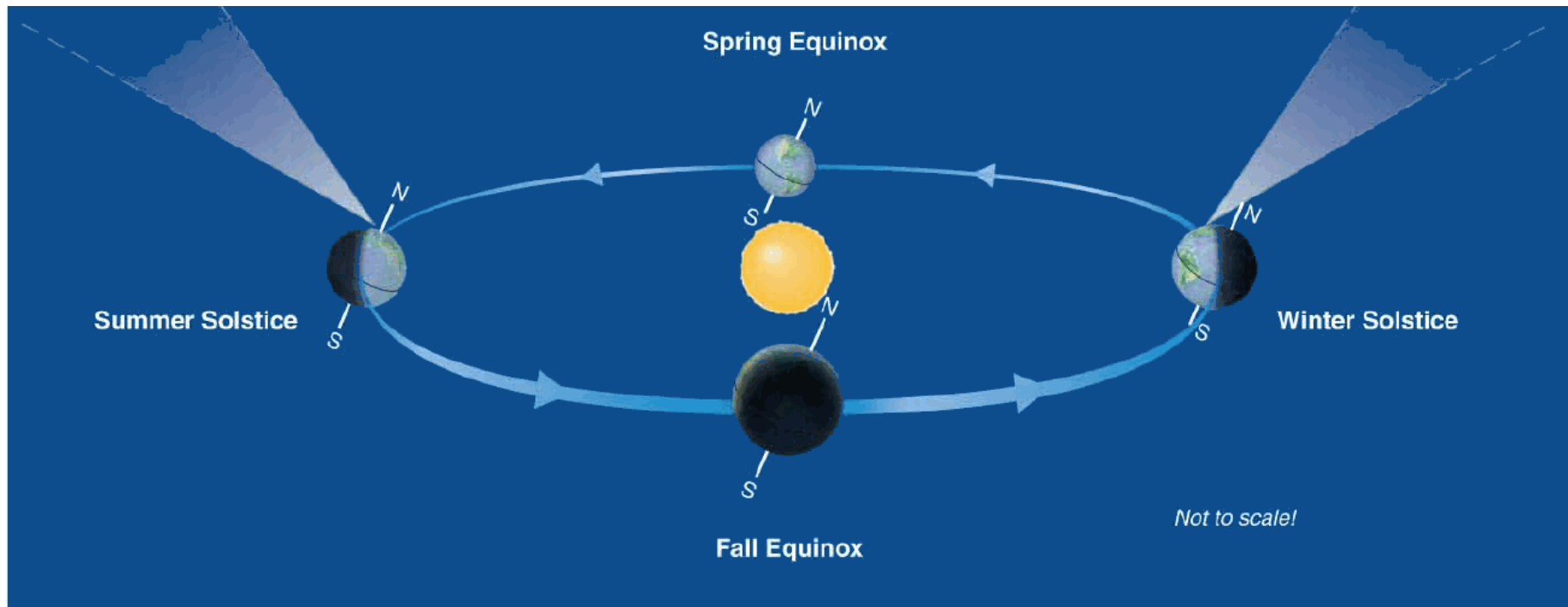
How do we mark the progression of the seasons?

Summer (June) solstice

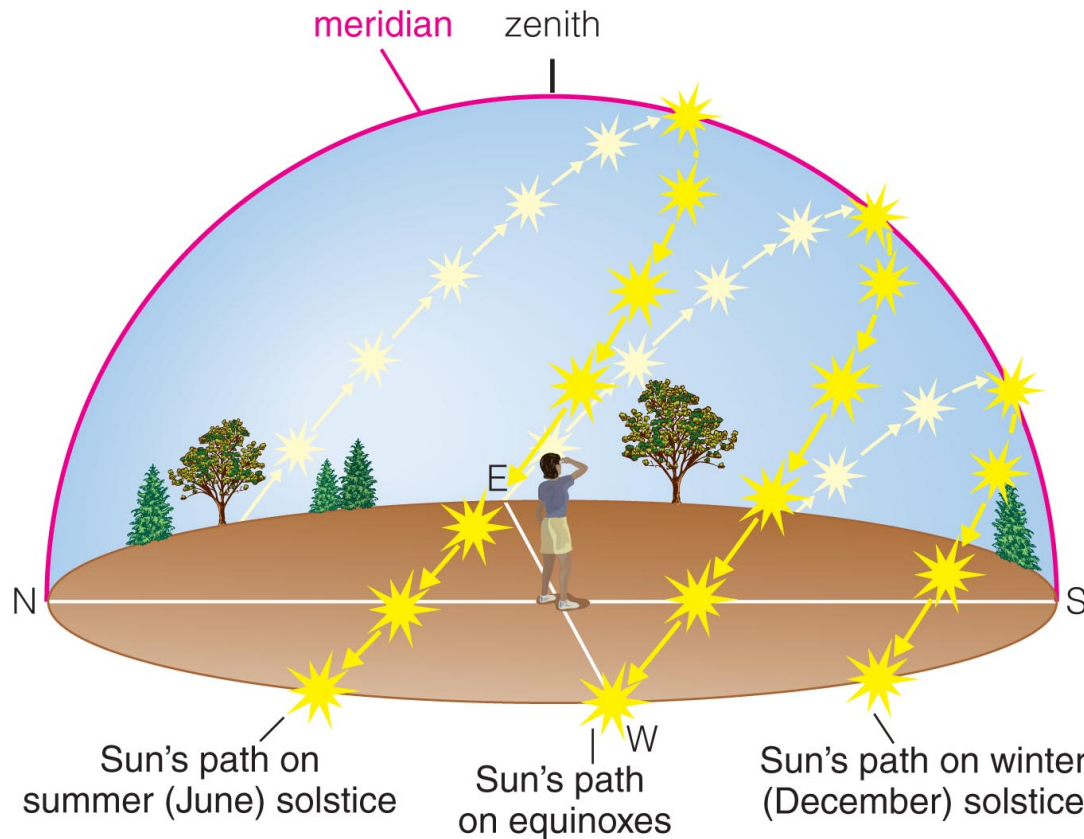
Winter (December) solstice

Spring (March) equinox

Fall (September) equinox



We can recognize solstices and equinoxes by Sun's path across sky:



Interactive Figure

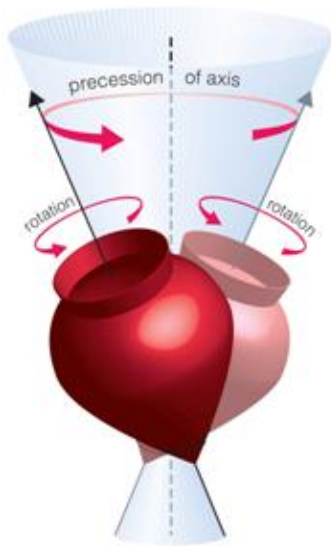
Summer (June)
solstice: highest path;
rise and set at most
extreme north of due
east

Winter (December)
solstice: lowest path;
rise and set at most
extreme south of due
east

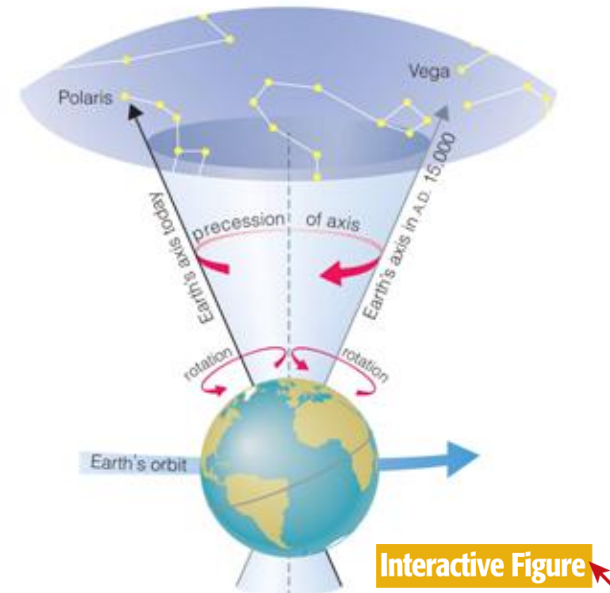
Equinoxes: Sun rises
precisely due east and
sets precisely due
west.

How does the orientation of Earth's axis change with time?

- Although the axis seems fixed on human time scales, it actually precesses over about 26,000 years.
 - ⇒ Polaris won't always be the North Star.
 - ⇒ Positions of equinoxes shift around orbit; e.g., spring equinox, once in *Aries*, is now in *Pisces*!



Earth's axis precesses like the axis of a spinning top



Interactive Figure

What have we learned?

- **What causes the seasons?**
 - The tilt of the Earth's axis causes sunlight to hit different parts of the Earth more directly during the summer and less directly during the winter.
 - We can specify the position of an object in the local sky by its **altitude** above the horizon and its **direction** along the horizon.
 - The **summer and winter solstices** are when the Northern Hemisphere gets its most and least direct sunlight, respectively. The **spring and fall equinoxes** are when both hemispheres get equally direct sunlight.

What have we learned?

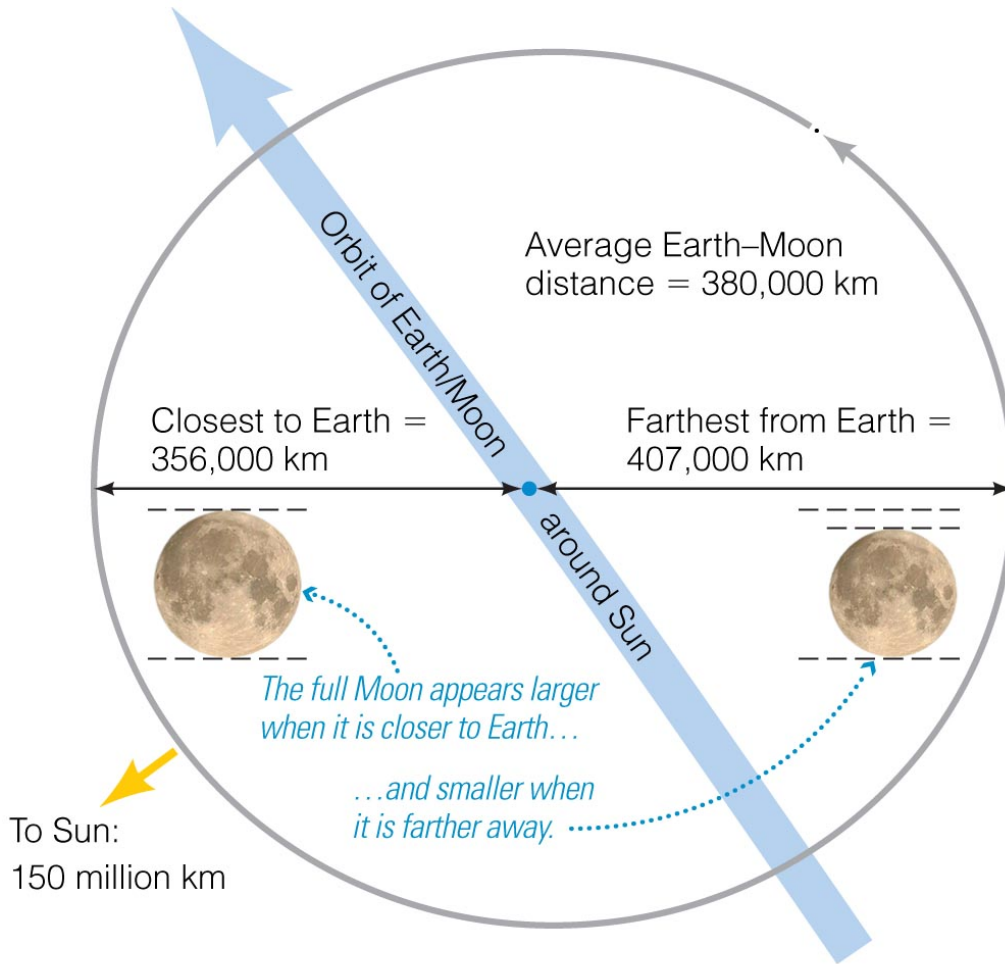
- **How does the orientation of Earth's axis change with time?**
 - The tilt remains about 23.5° (so the season pattern is not affected), but Earth has a 26,000 year precession cycle that slowly and subtly changes the orientation of Earth's axis.

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?

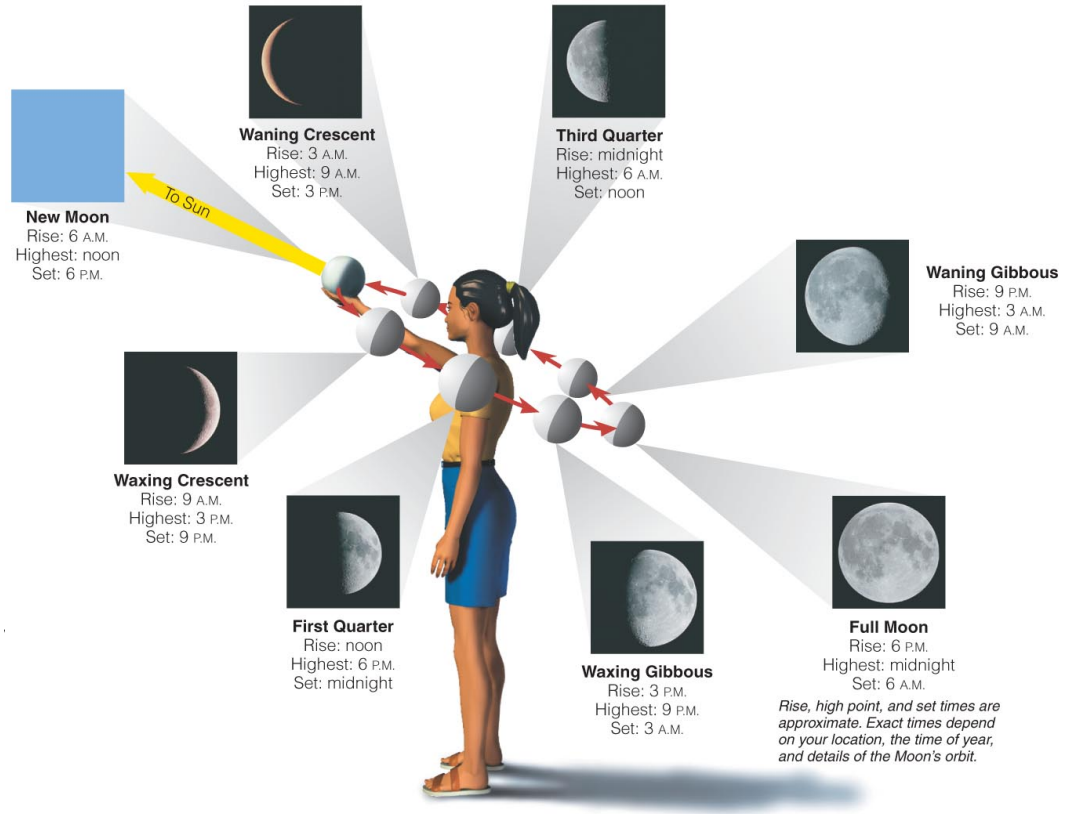
Lunar phases are a consequence of the Moon's 27.3-day orbit around Earth.



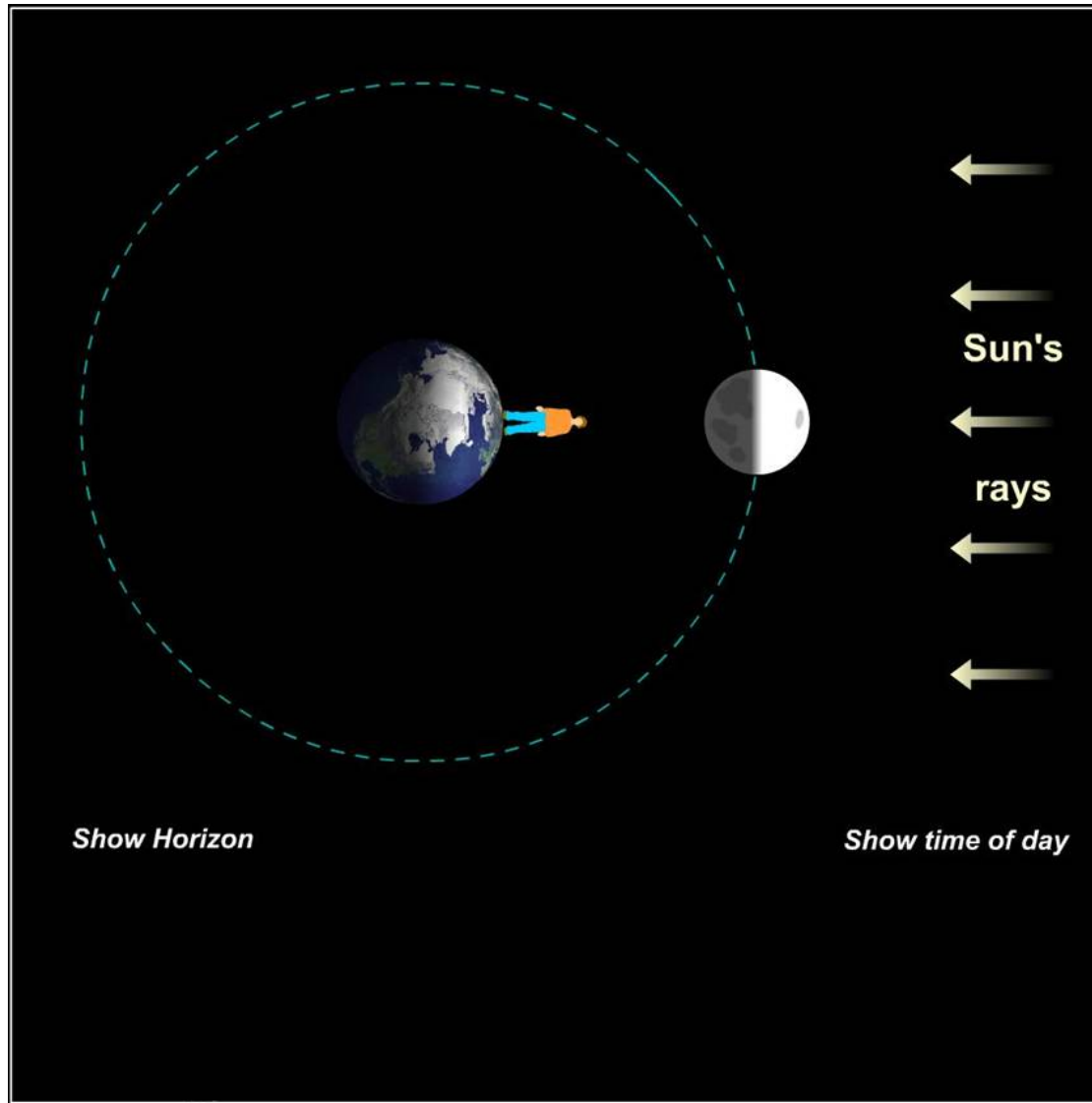
Phases of the Moon

Half of Moon is illuminated by Sun and half is dark.

We see a changing combination of the bright and dark face as Moon orbits.

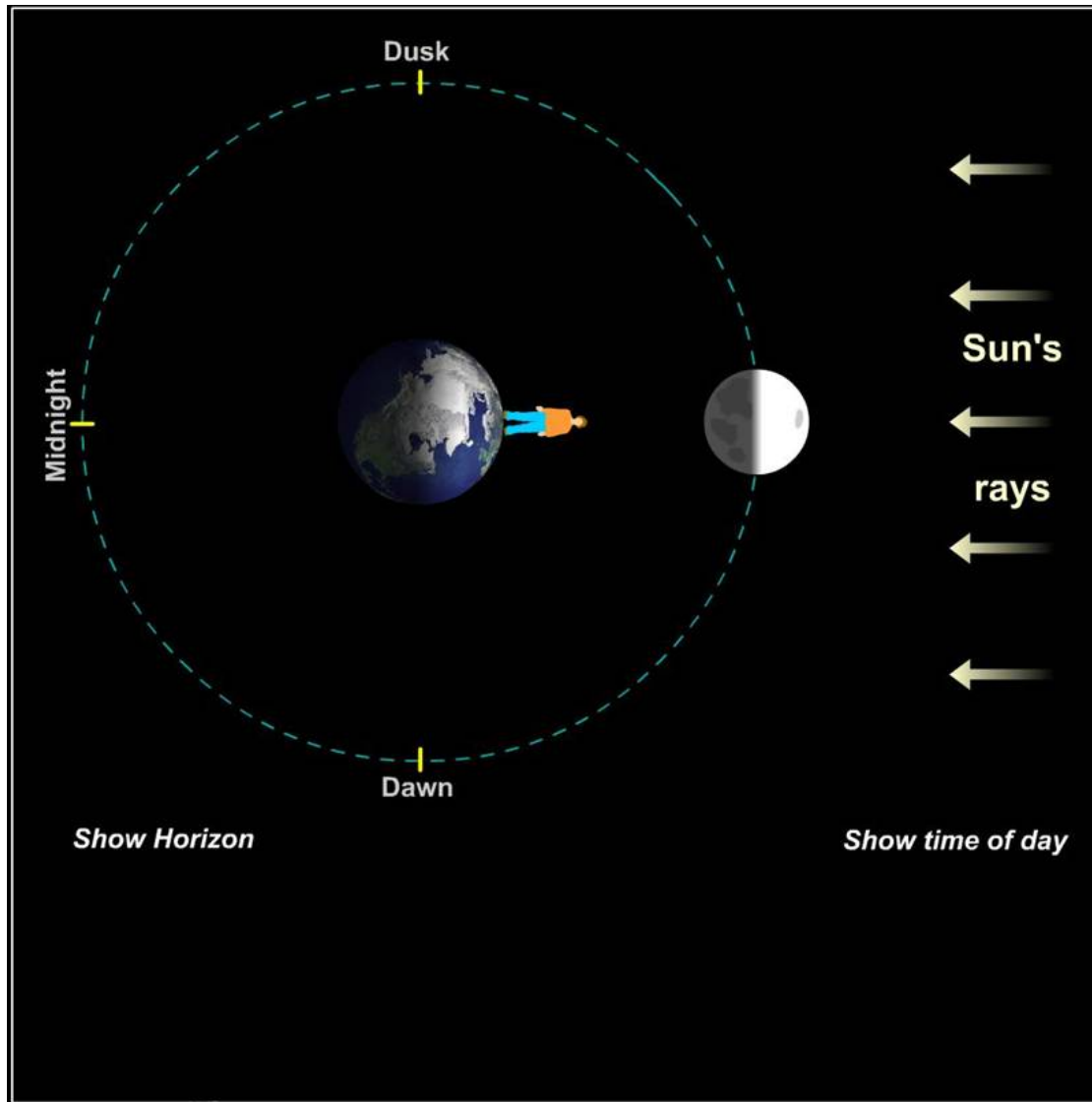


Phases of the Moon



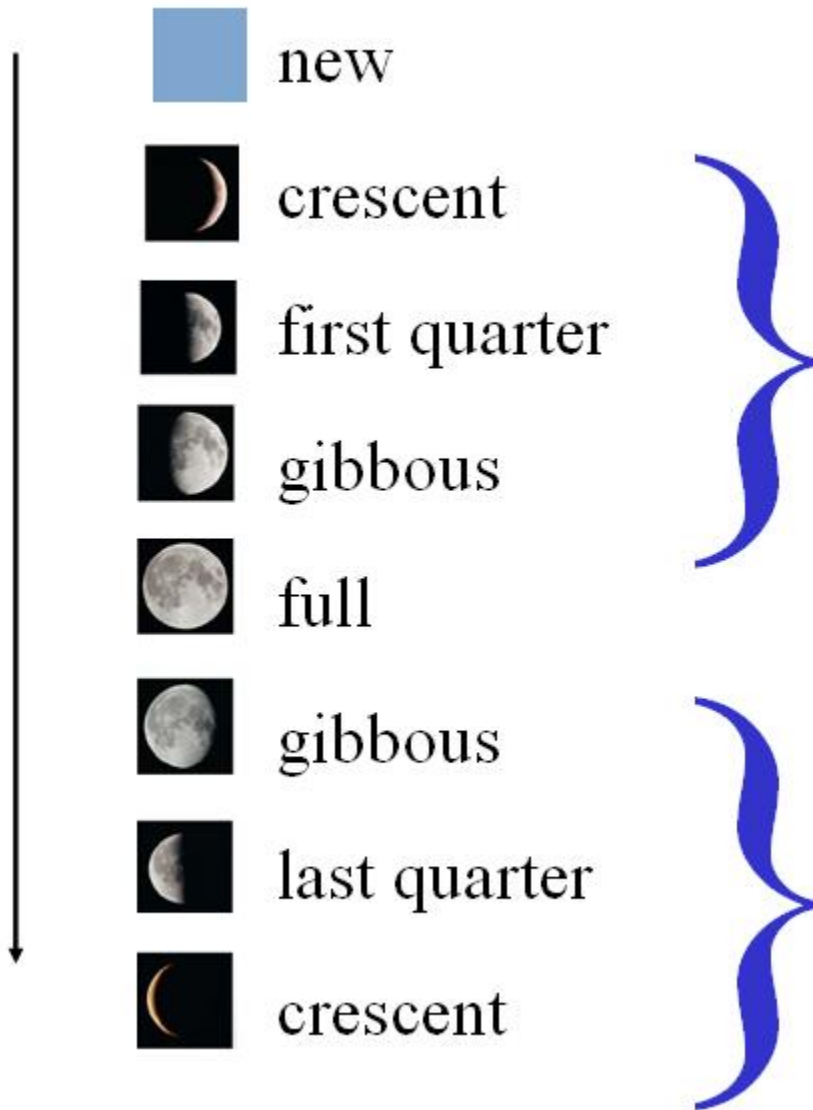
Interactive Figure

Moon Rise/Set by Phase



Interactive Figure 

Phases of the Moon: 29.5-day cycle



Waxing

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

Waning

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

Thought Question

It's 9 a.m. You look up in the sky and see a moon with half its face bright and half dark. What phase is it?

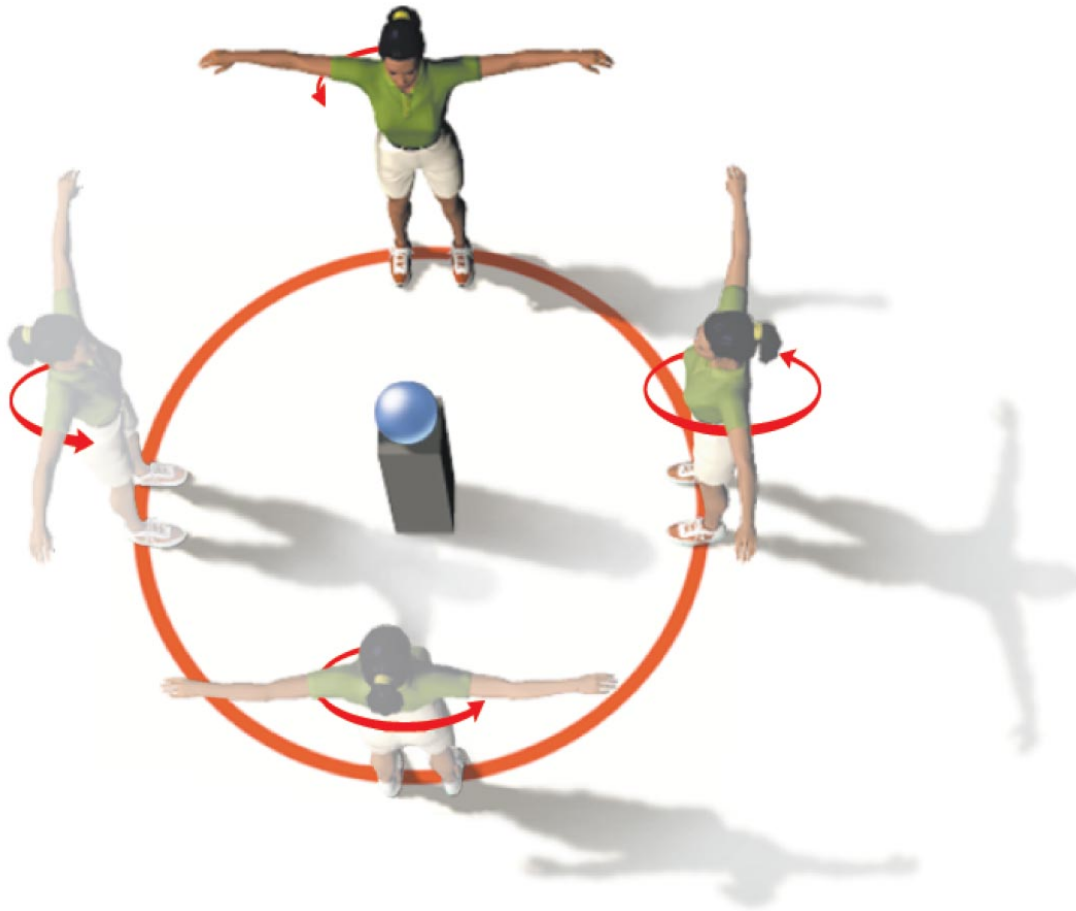
- A. first quarter
- B. waxing gibbous
- C. third quarter
- D. half moon

Thought Question

It's 9 a.m. You look up in the sky and see a moon with half its face bright and half dark. What phase is it?

- A. first quarter
- B. waxing gibbous
- C. third quarter**
- D. half moon

We see only one side of Moon

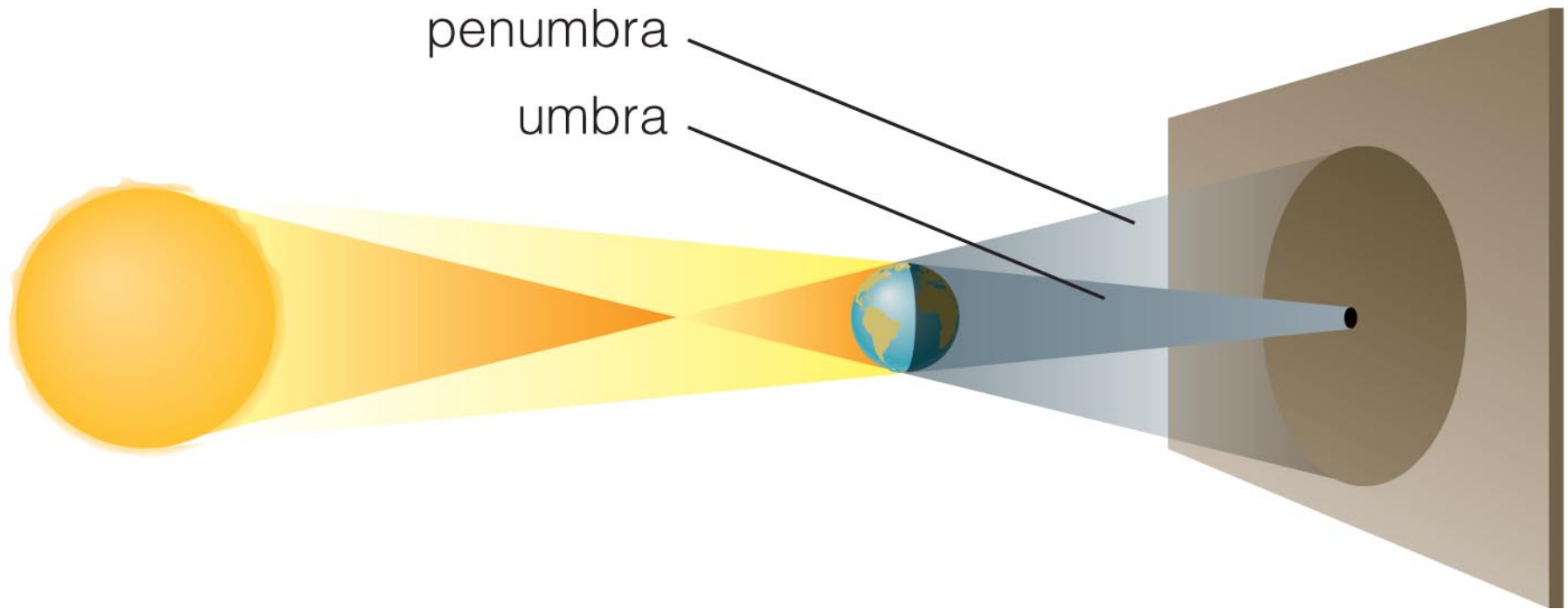


Synchronous rotation: the Moon rotates exactly once with each orbit.

That is why only one side is visible from Earth.

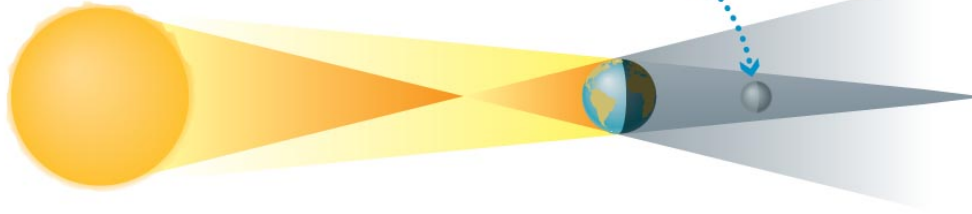
What causes eclipses?

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



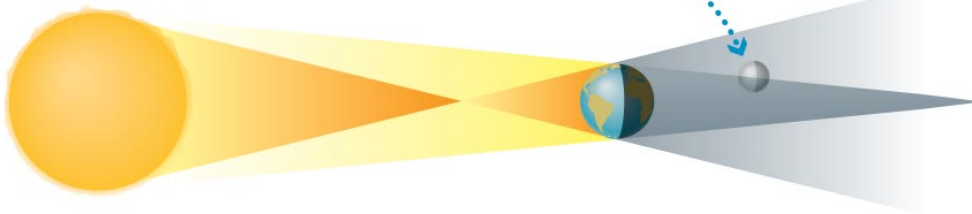
Lunar Eclipse

Moon passes entirely through umbra.



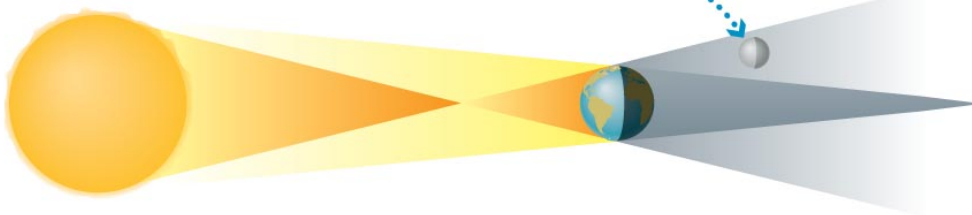
Total Lunar Eclipse

Part of the Moon passes through umbra.



Partial Lunar Eclipse

Moon passes through penumbra.

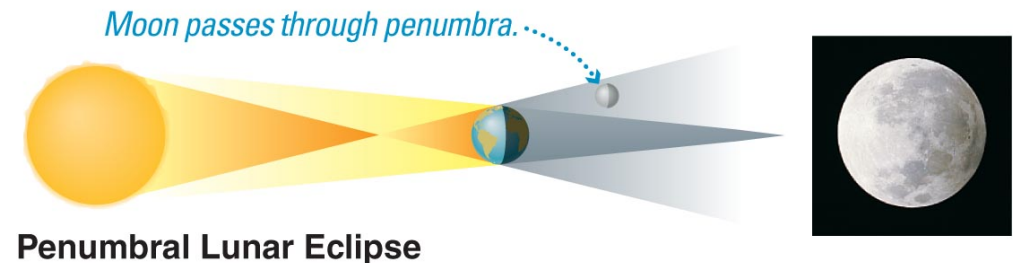
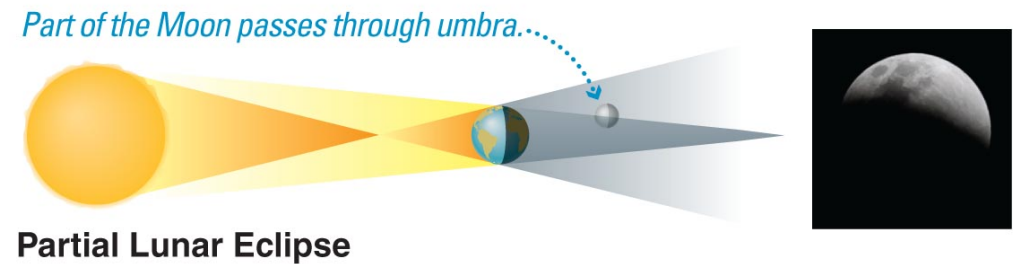
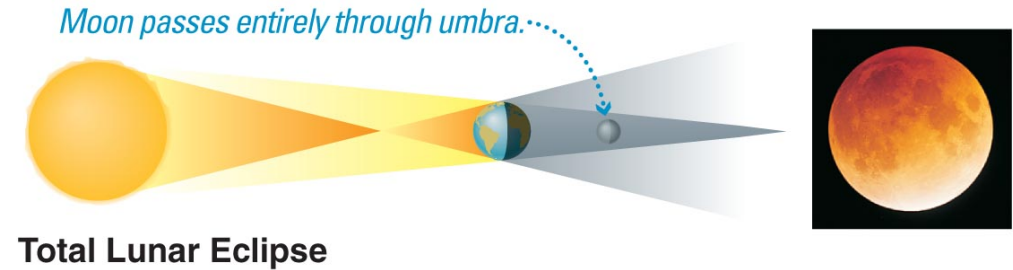


Penumbral Lunar Eclipse

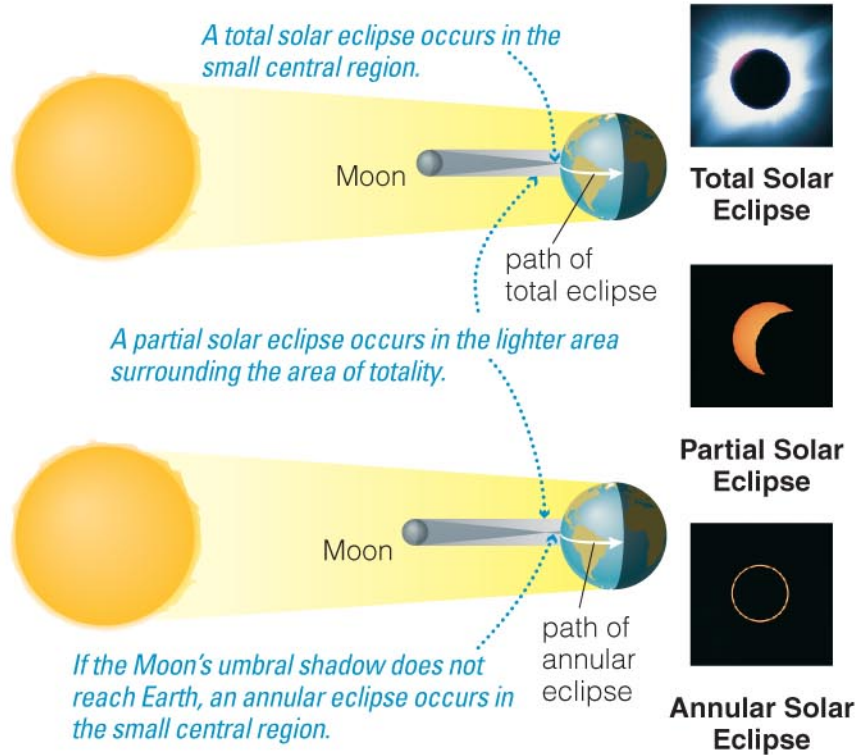
Interactive Figure 

When can eclipses occur?

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



Solar Eclipse



a The three types of solar eclipse. The diagrams show the Moon's shadow falling on Earth; note the dark central umbra surrounded by the much lighter penumbra.



b This photo from Earth orbit shows the Moon's shadow (umbra) on Earth during a total solar eclipse. Notice that only a small region of Earth experiences totality at any one time.

Interactive Figure 

When can eclipses occur?

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

