

Astronomy 100

Chapter 3

The Moon

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The Moon

- The Moon is Earth's only natural satellite.
- Average orbital distance: 384,400 km.
- Diameter: 3,476 km (about 1/4 of Earth).
- Mass: 7.35×10^{22} kg (80 times lighter than Earth).
- The Moon's orbit is inclined by 5° to the ecliptic.
- Only extraterrestrial body visited by humans to-date.
- Formed by the impact of Earth with a large celestial body.



Plan for this lesson:

Phases of the moon
Eclipses
Moon's rotation
Formation of the Moon

Phases

Changing phases of the Moon inspired the concept of a ***month***.



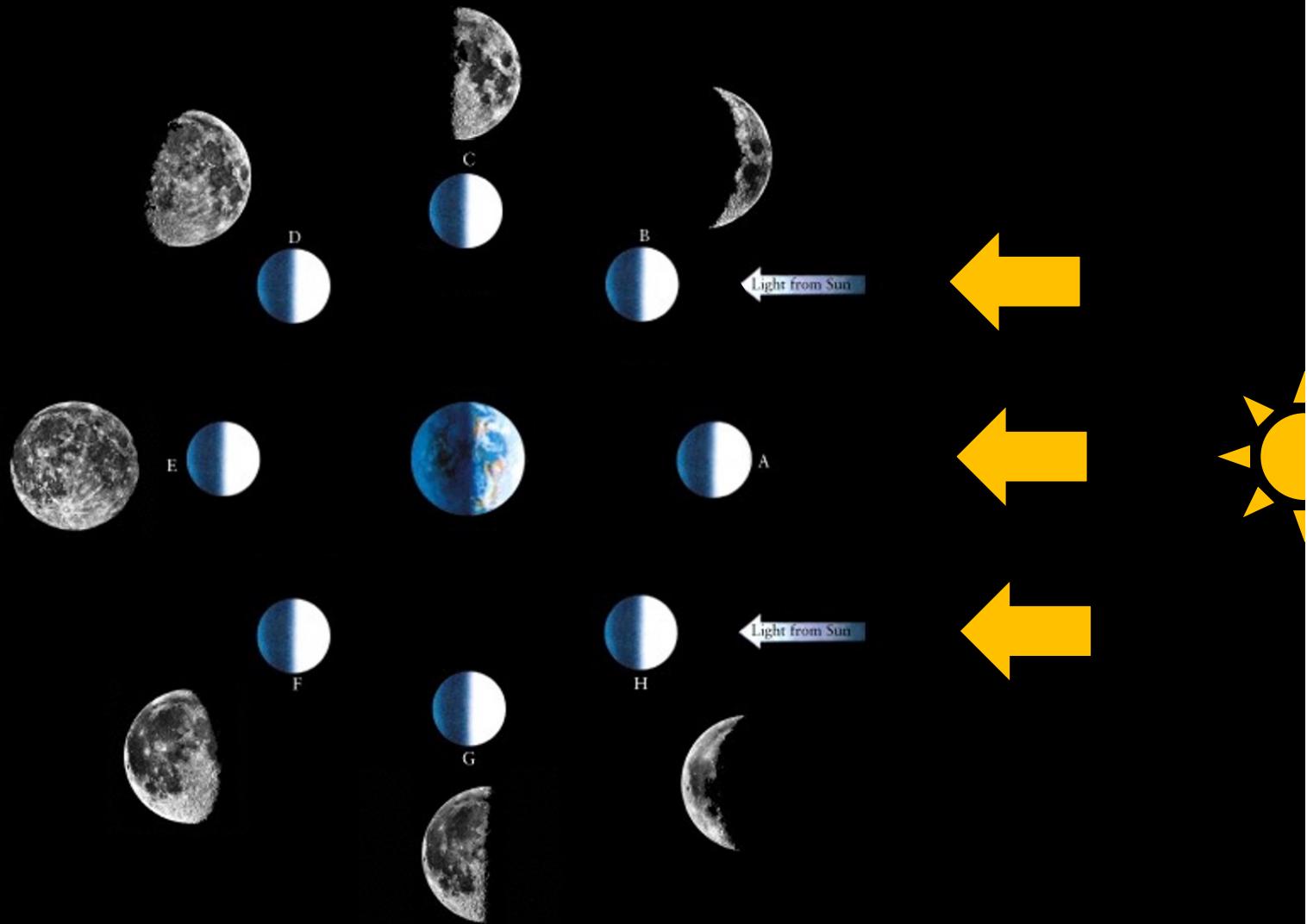
Phases of the moon:

New Moon
Waxing Crescent
First Quarter
Waxing Gibbous
Full Moon
Waning Gibbous
Third Quarter
Waning Crescent



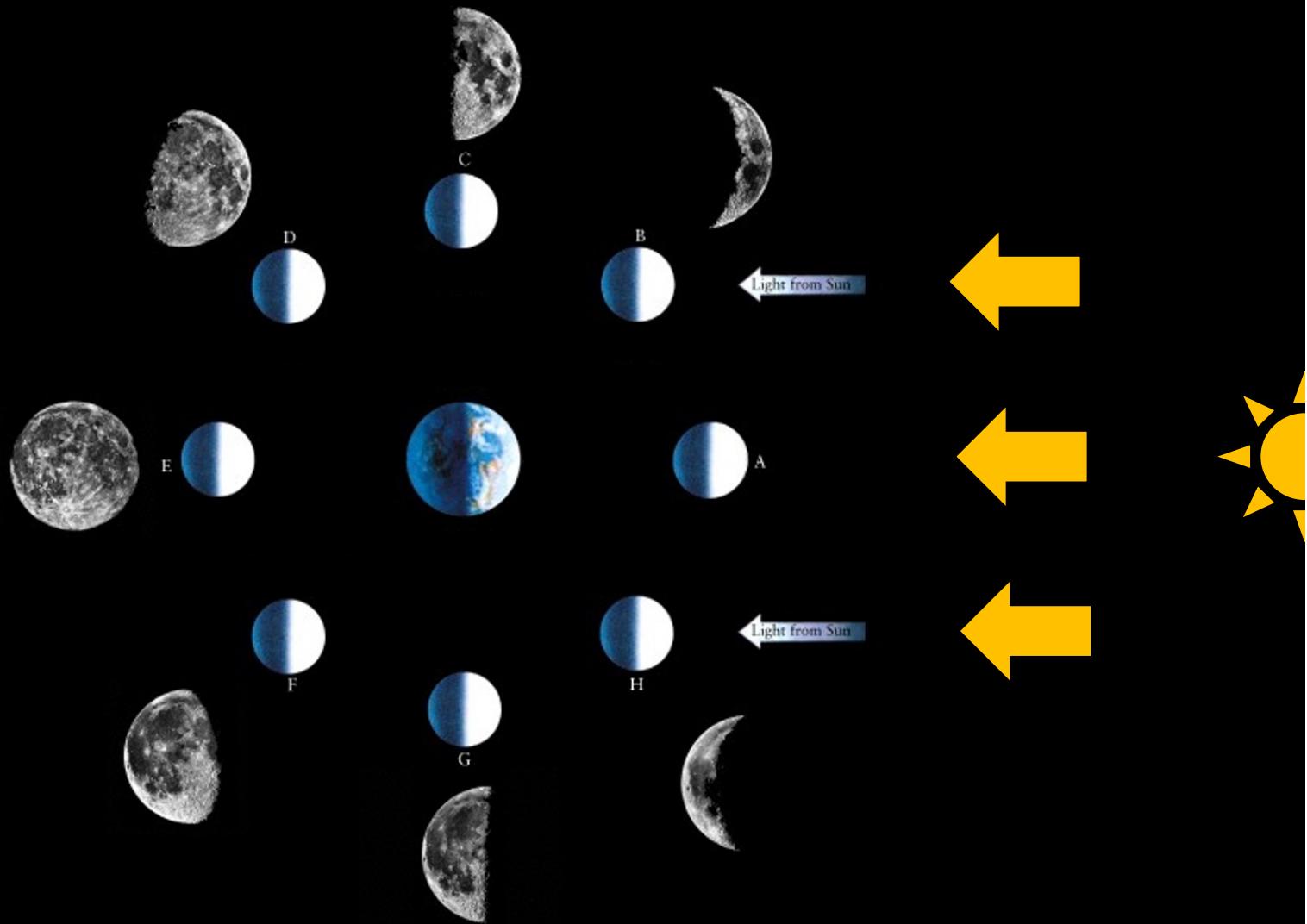
What causes the phases of the Moon?

Moon's Phases



As it goes around the Earth once every ~28 days,
how much of it is illuminated?

Moon's Phases



Although the Moon is always $\frac{1}{2}$ lit by the Sun, we see different amounts of the lit portion from Earth, depending on where the Moon is located in its month-long orbit.

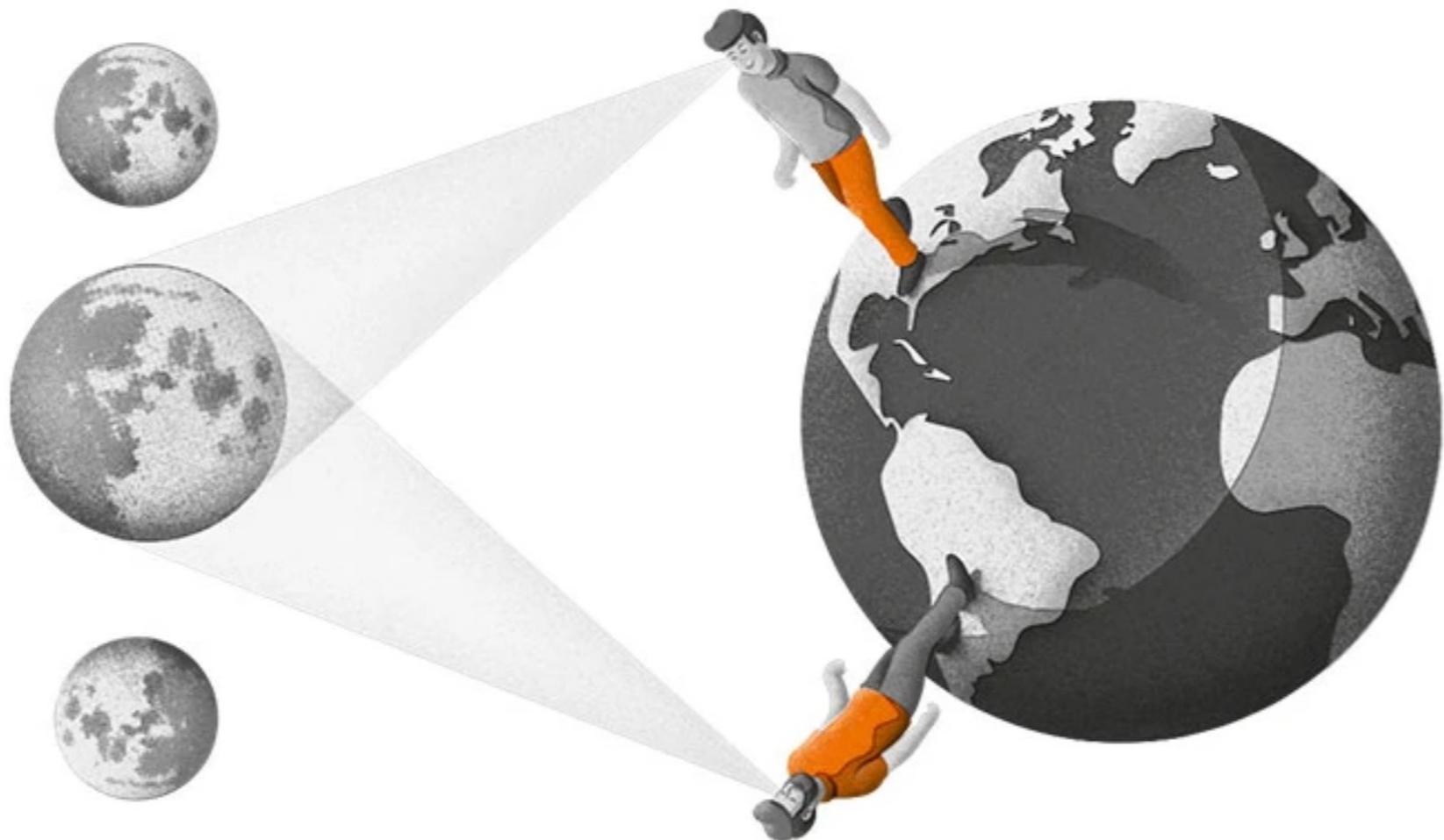
question for you



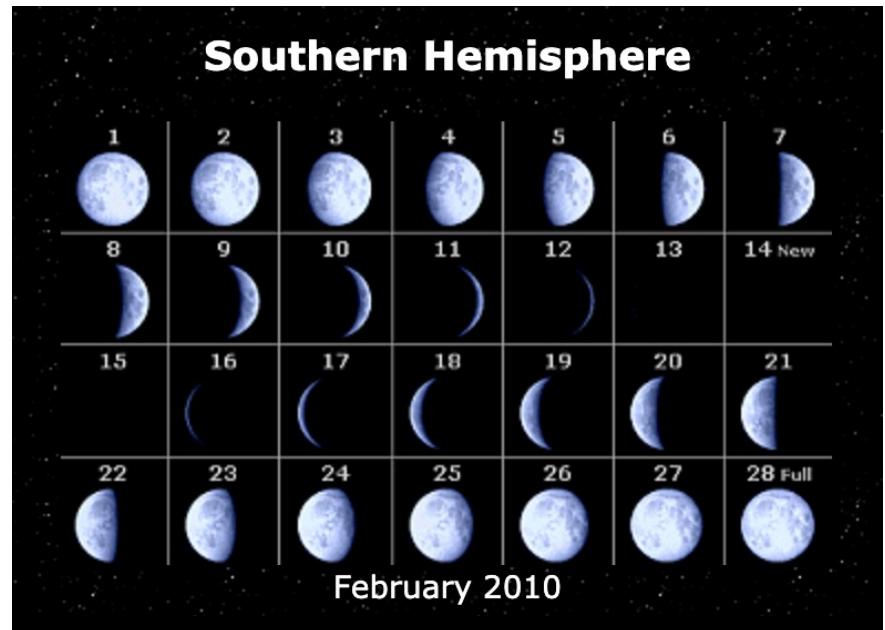
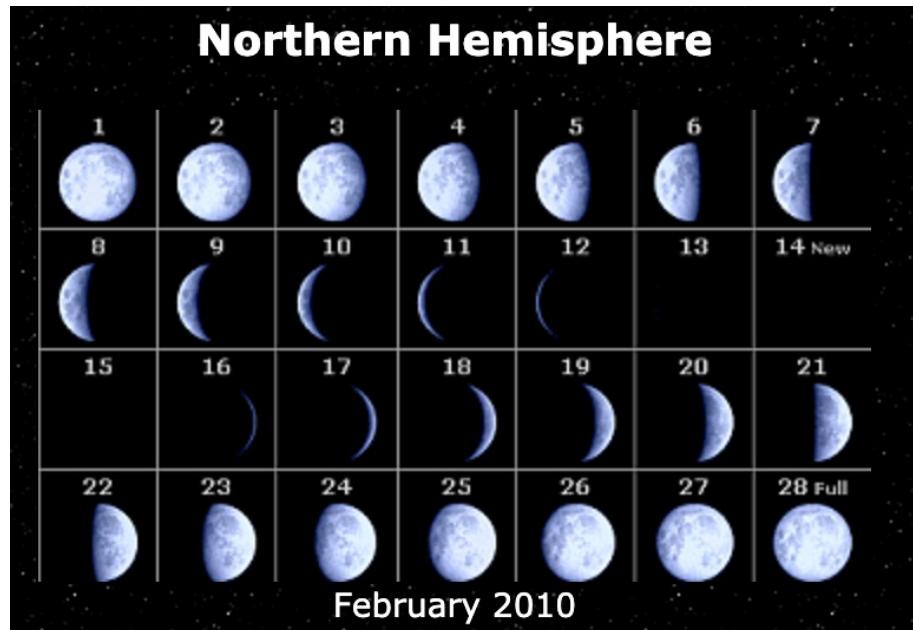
If the moon is a waning crescent as seen from LA, what phase would it be in Buenos Aires?

- A. New Moon
- B. First Quarter
- C. Waning Crescent
- D. Waxing Crescent
- E. I have no idea.

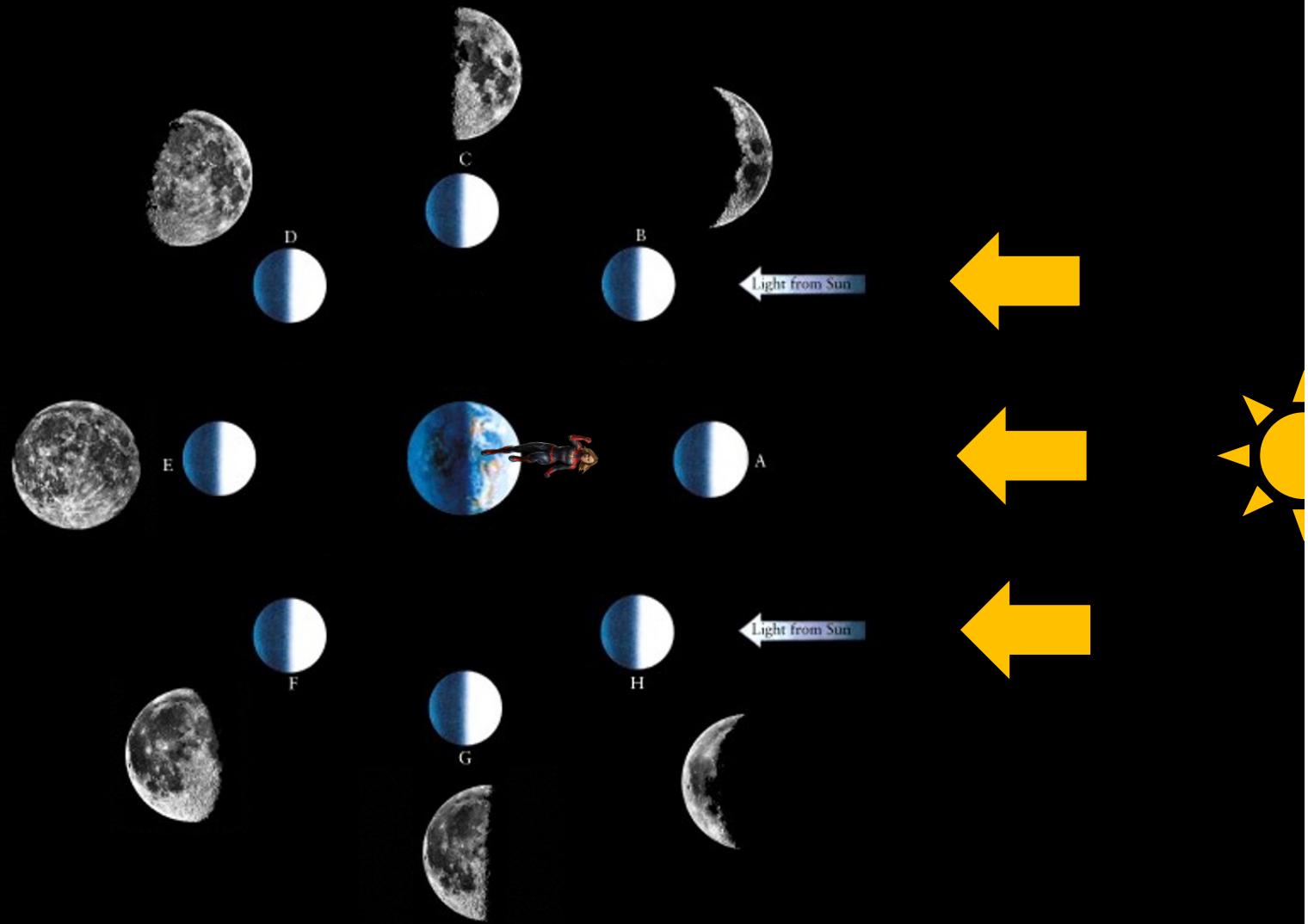
N vs. S hemisphere:
The Moon is “upside down.”



N vs. S hemisphere: Terminator moves in opposite directions (when facing the moon).

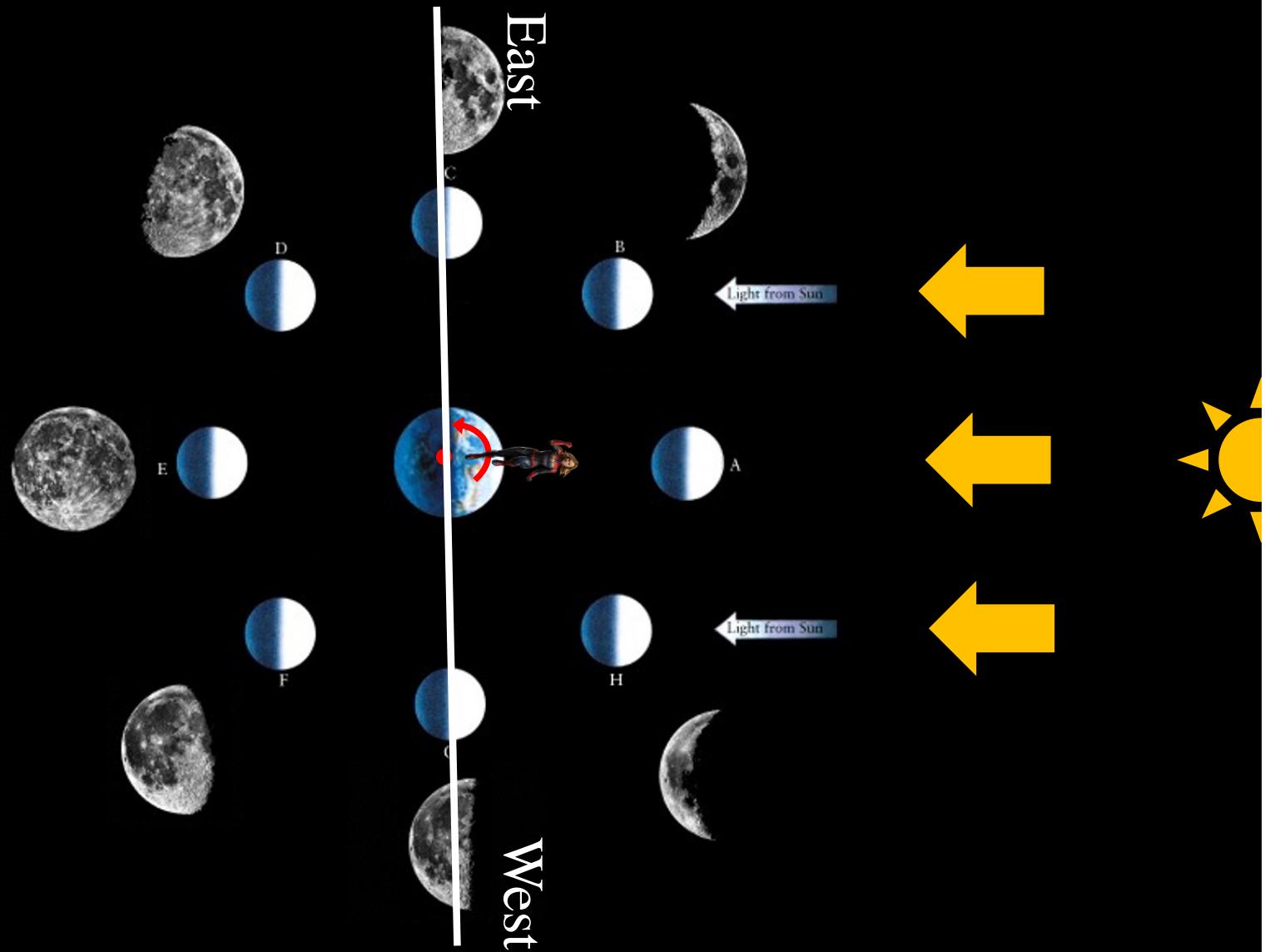


Moon's Phases



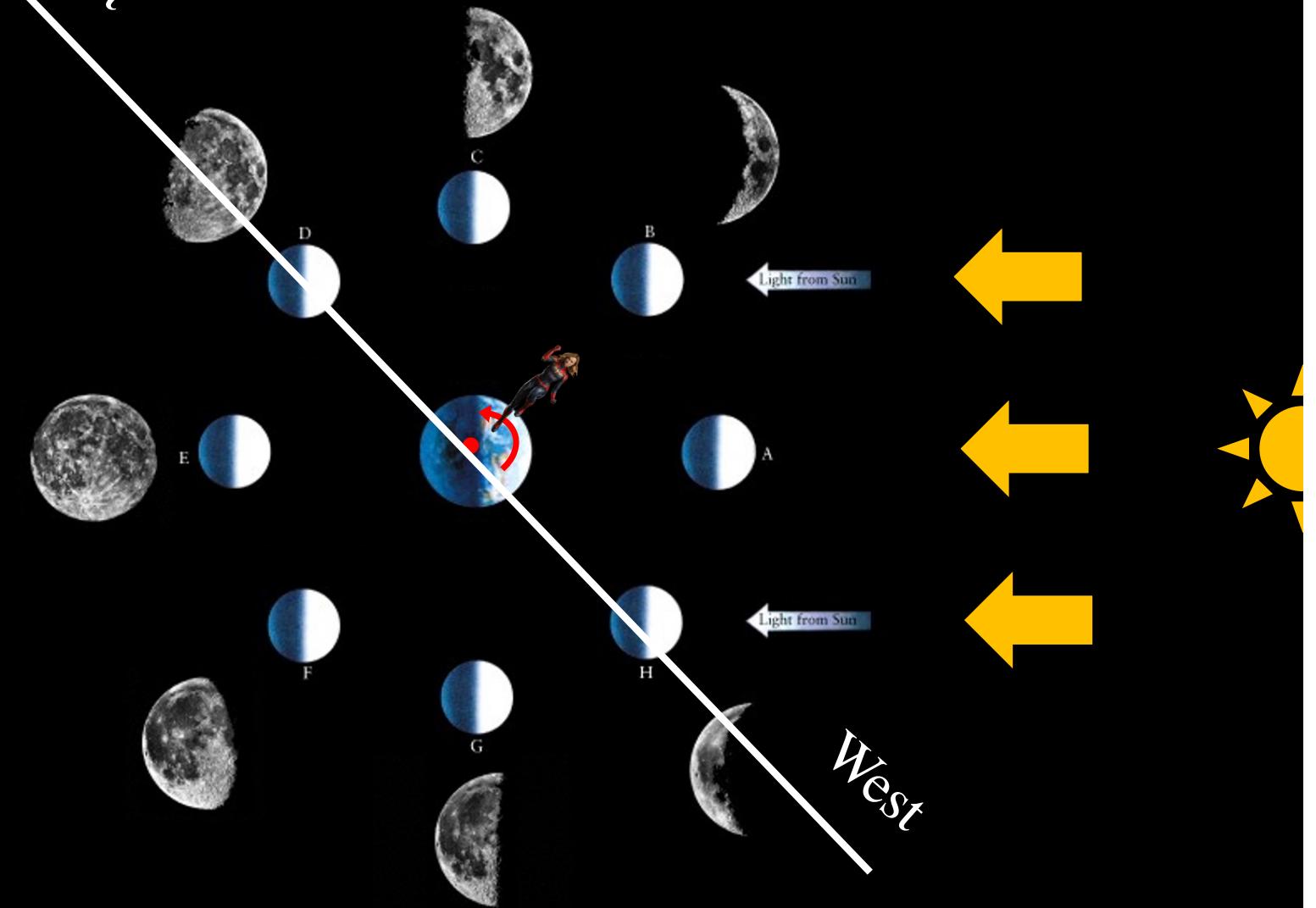
Let's consider an observer!

Moon's Phases



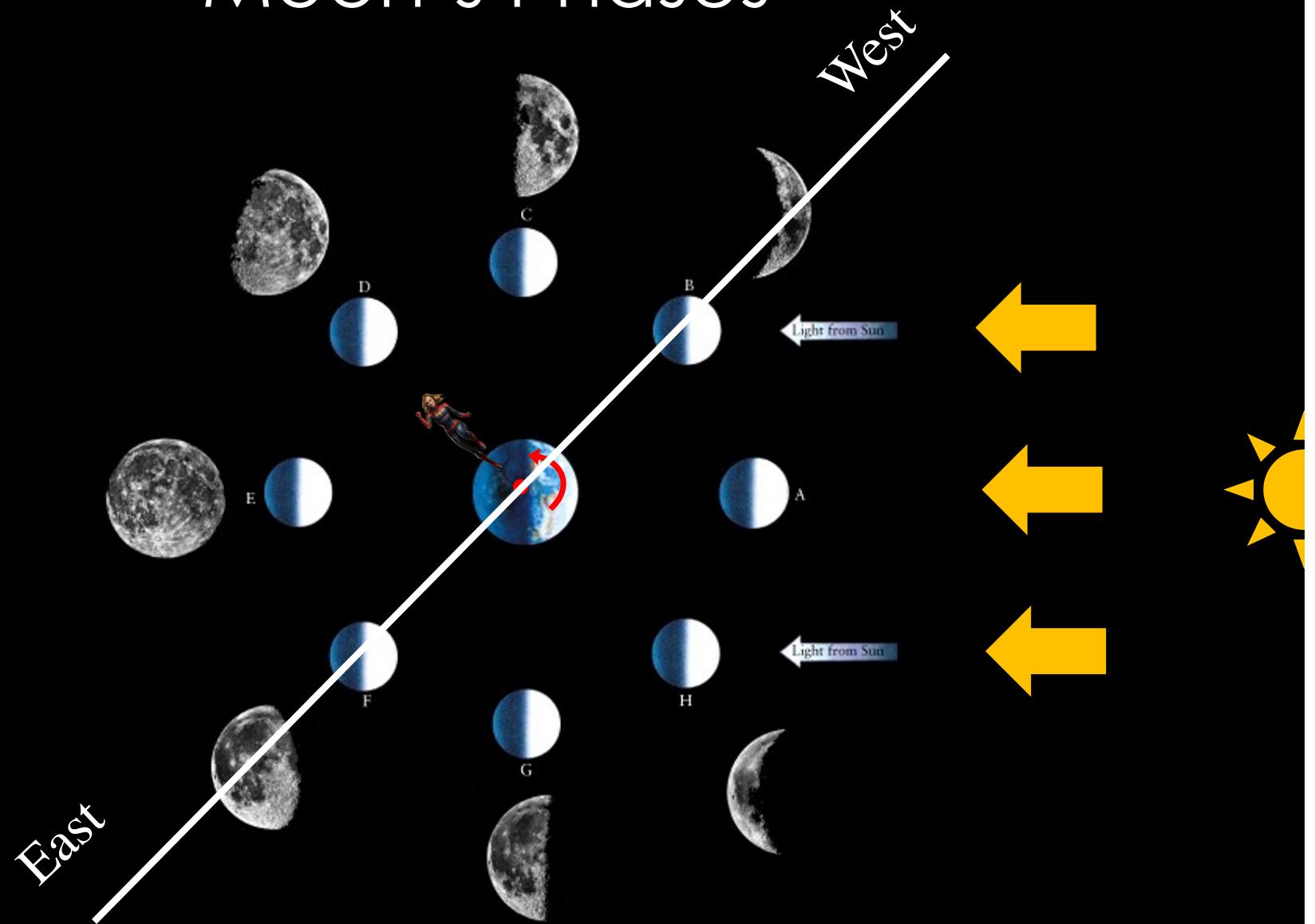
What time is it for Marvel right now?

Moon's Phases



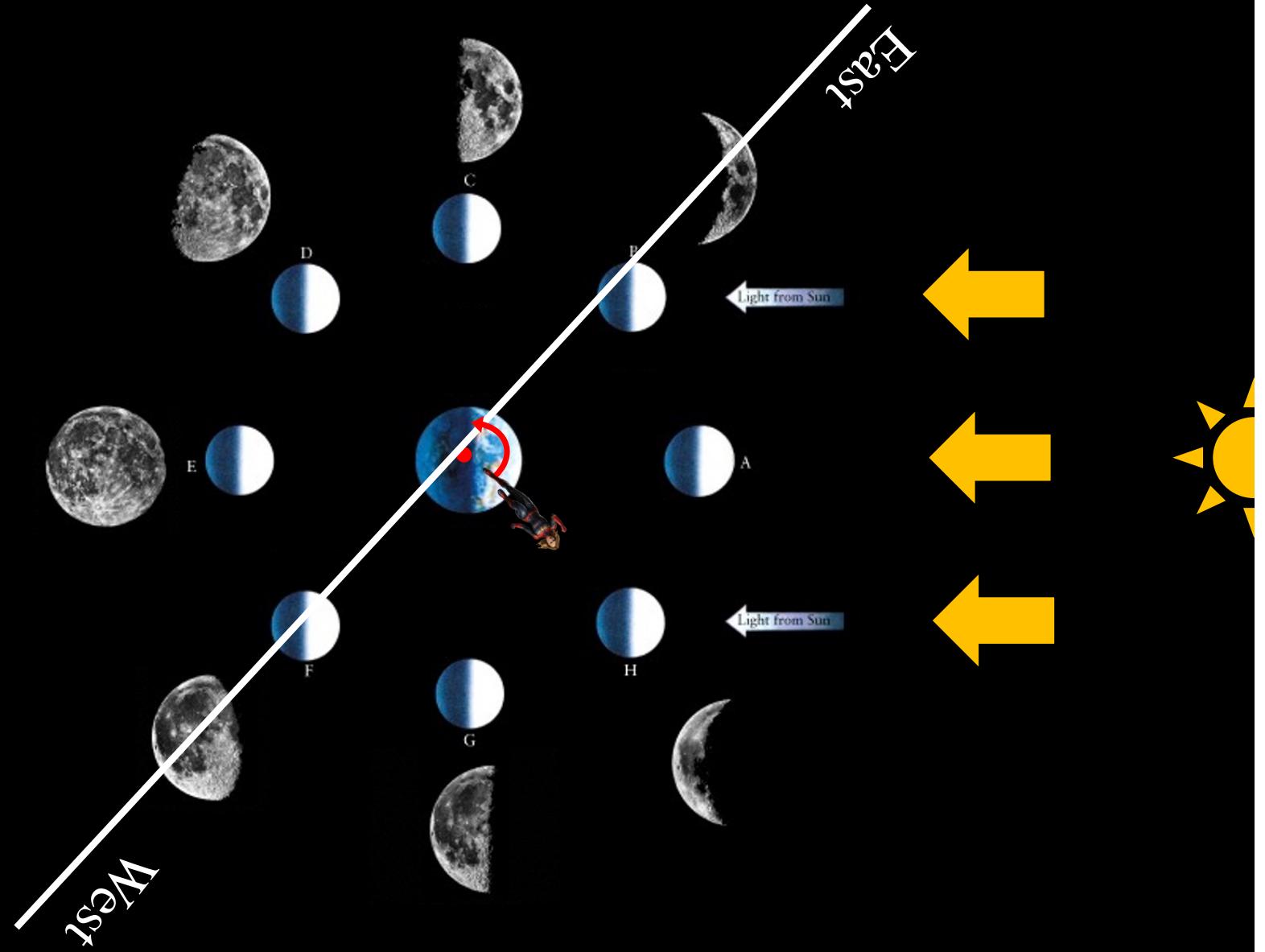
How about now?

Moon's Phases



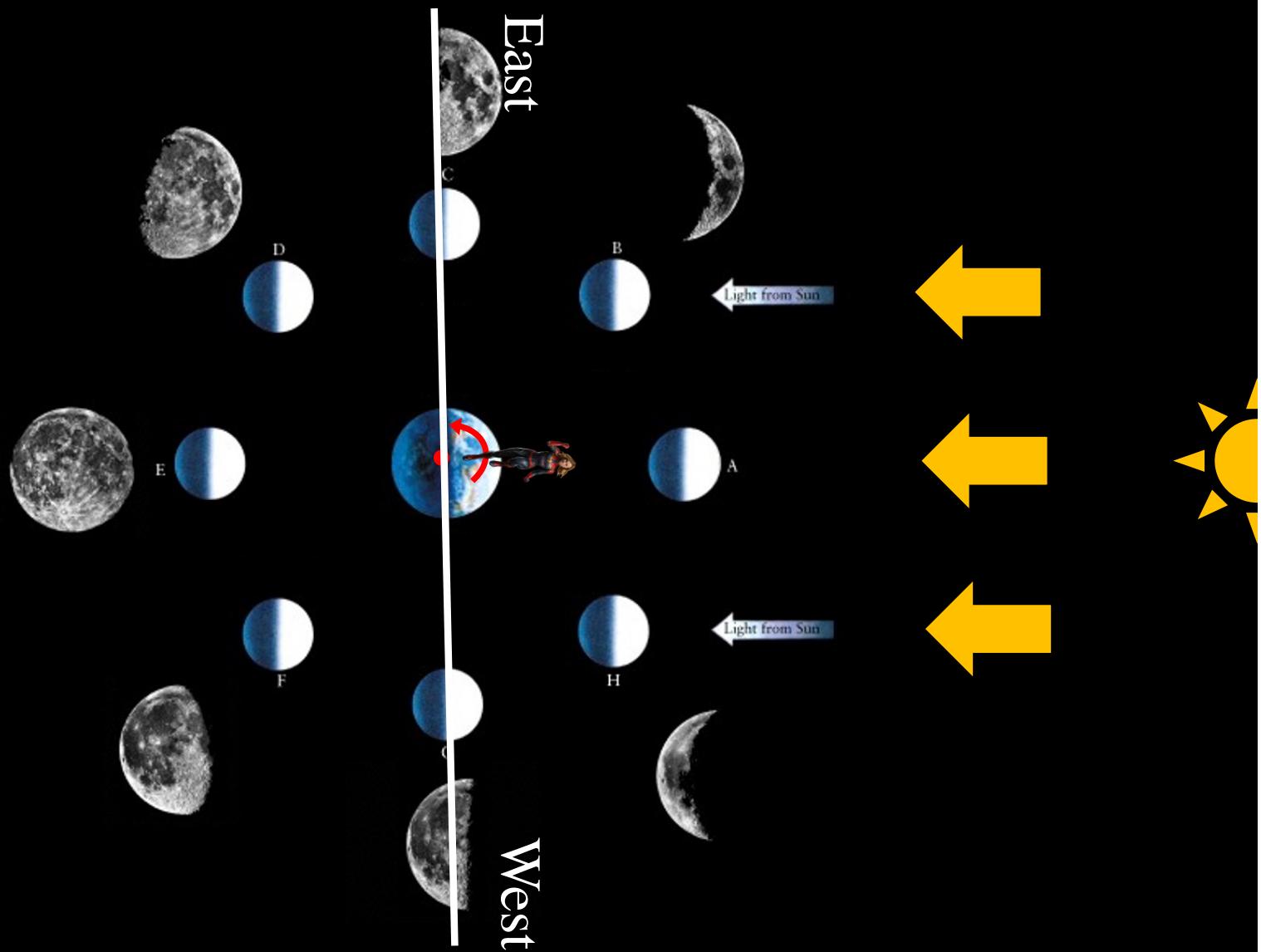
And now?

Moon's Phases



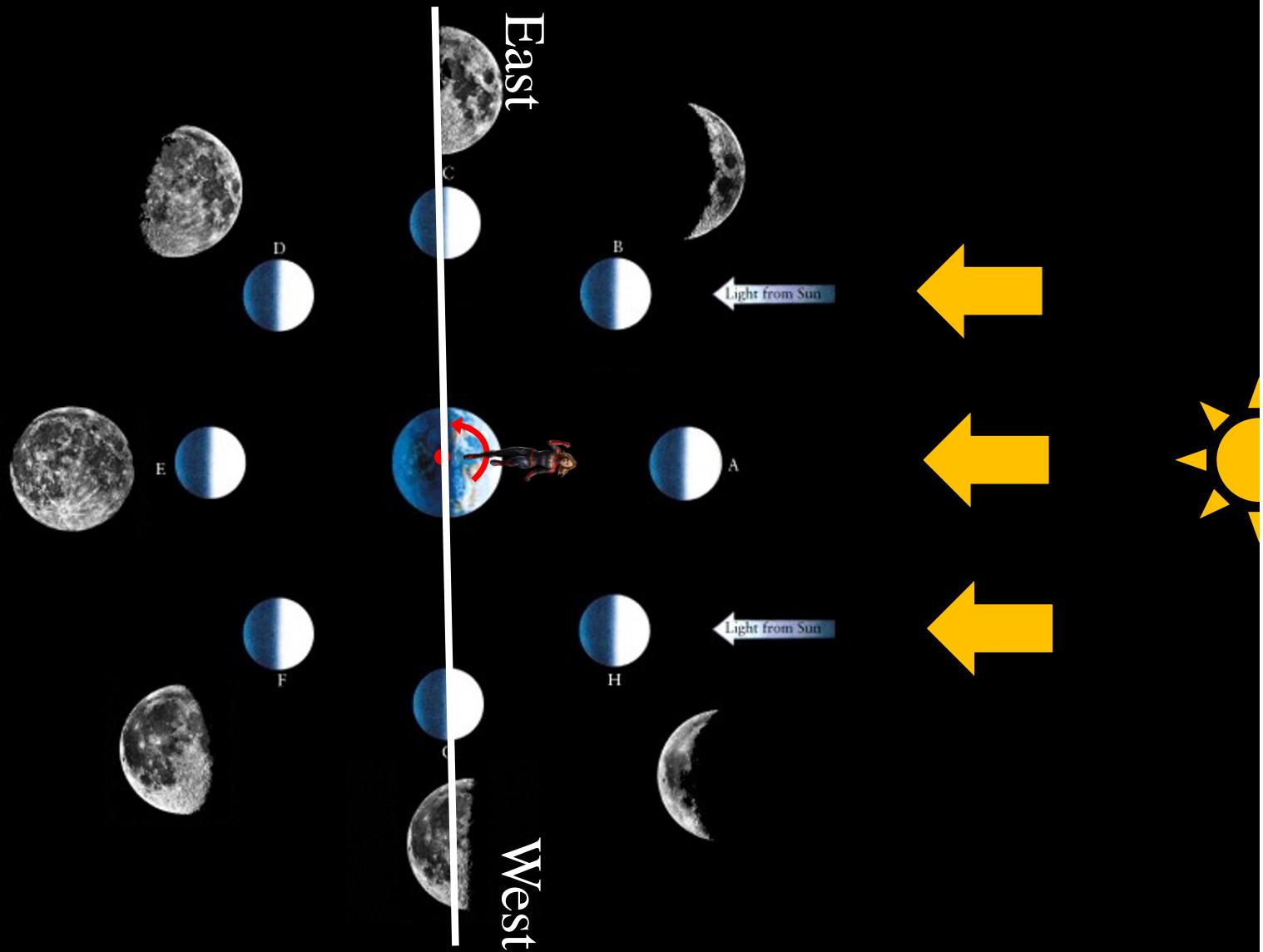
Now?

Moon's Phases



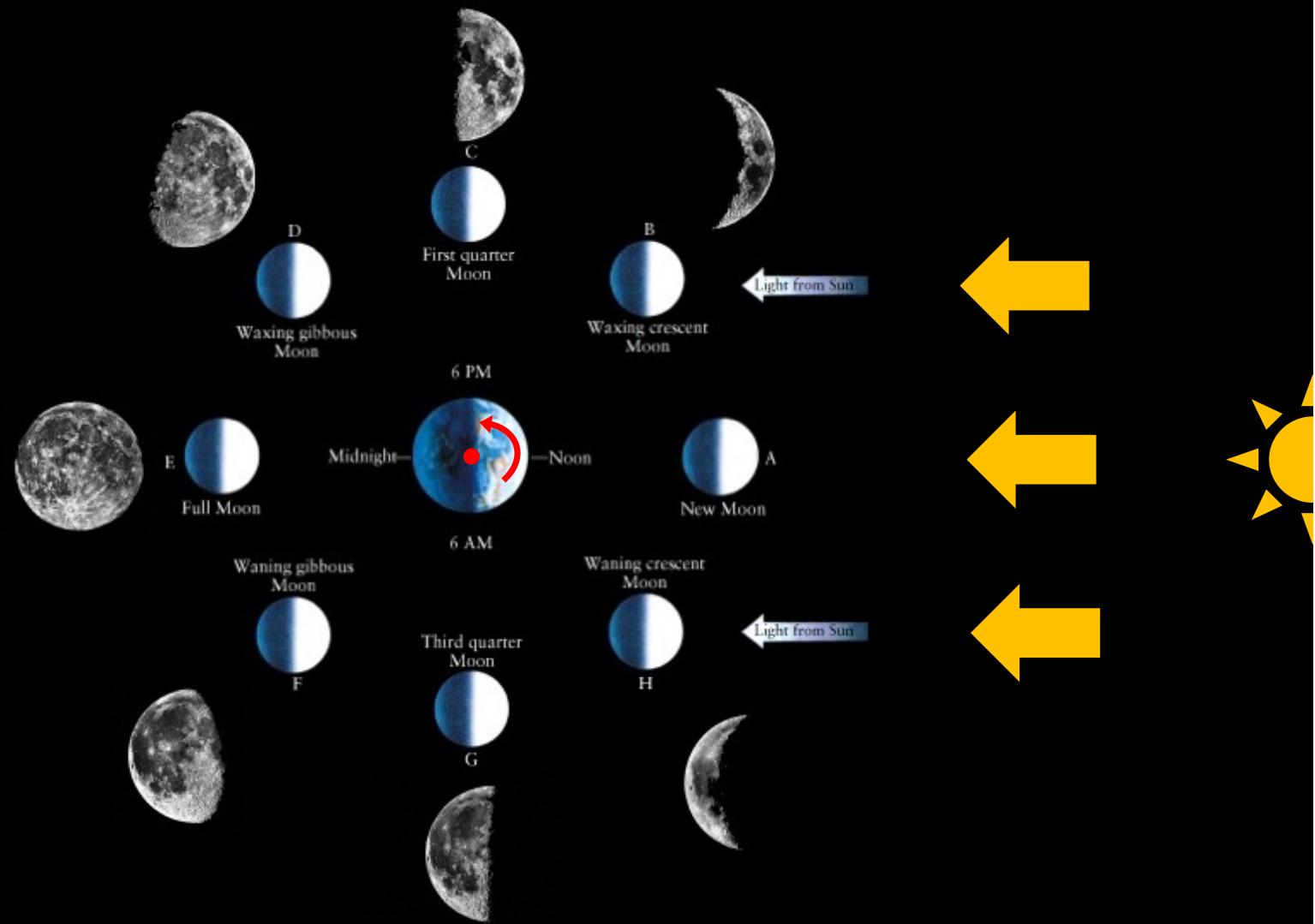
Which phase is high in the sky at noon?

Moon's Phases



And which phase would be setting at noon?

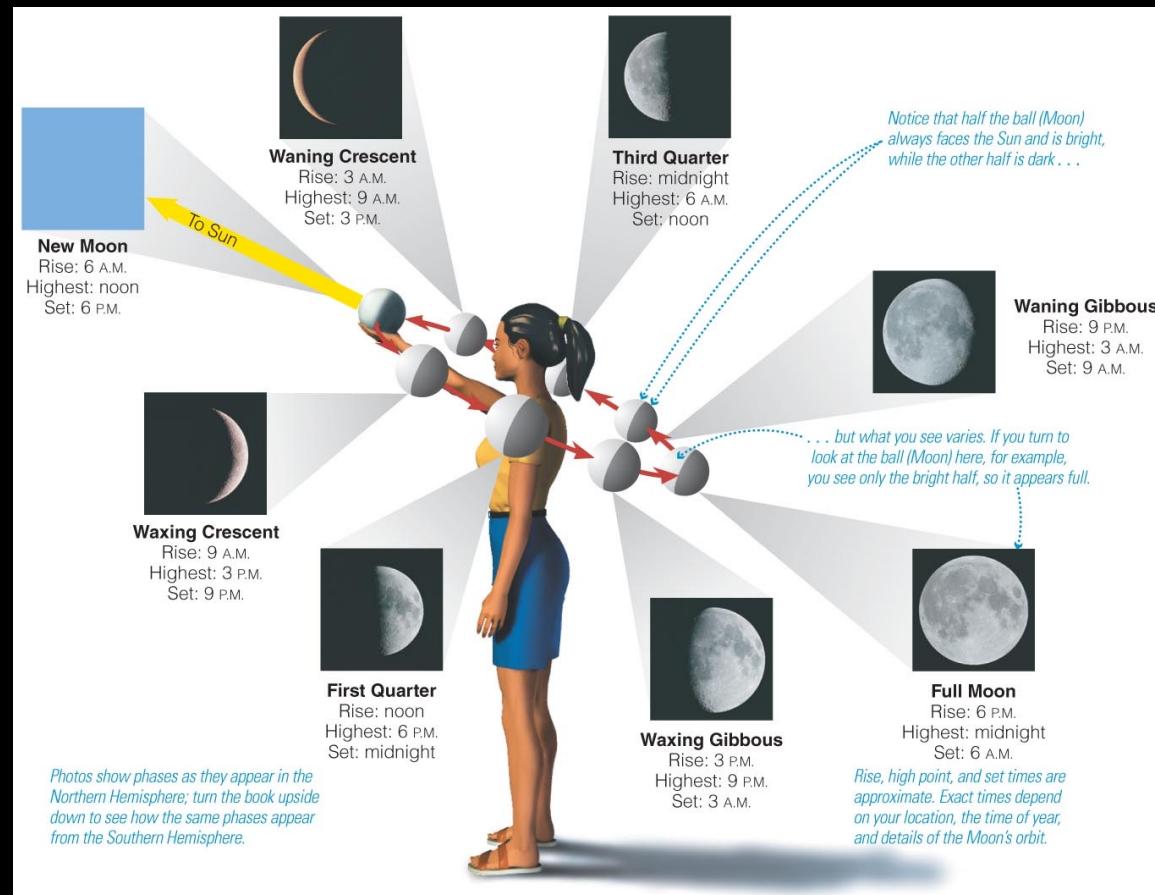
Moon's Phases



Different phases are visible at different times of the day, because the moon rises approx. **50 minutes later each day.**

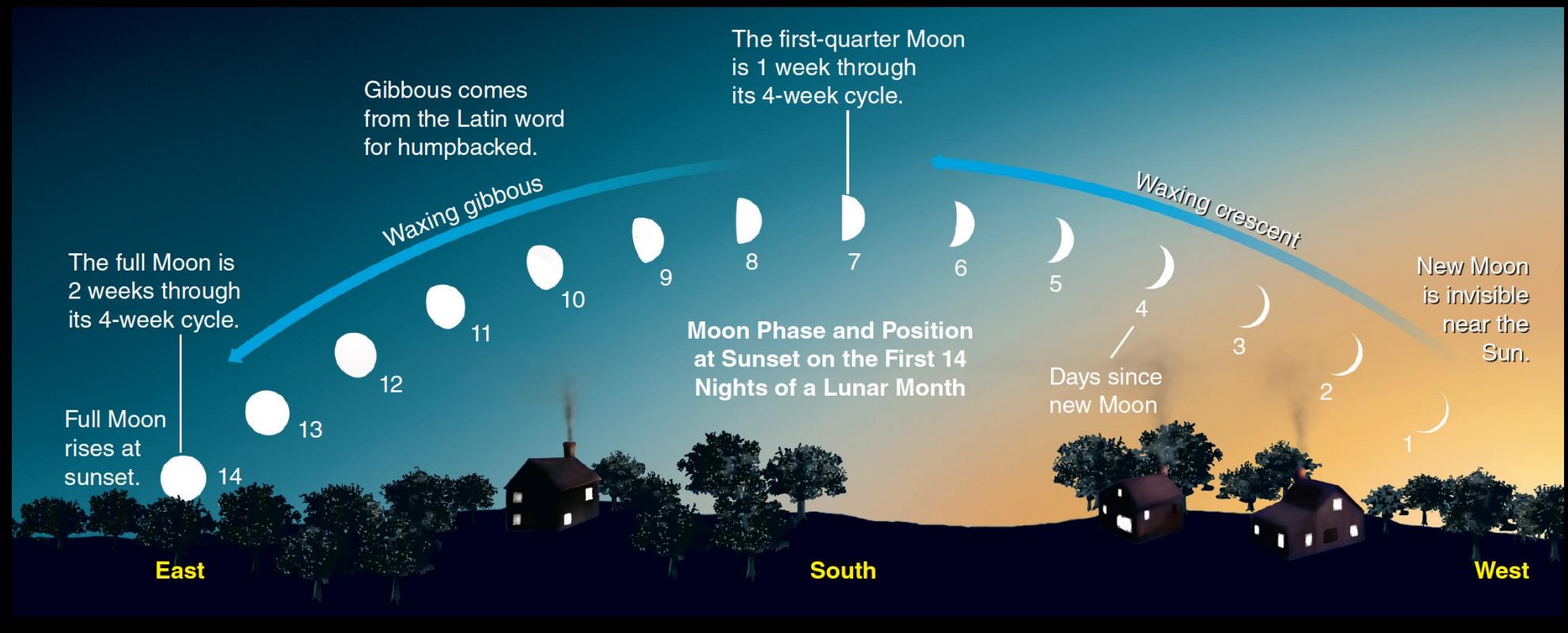
Moon's Phases

When it's approaching the sun, it's waning, when it's moving away, it's waxing.



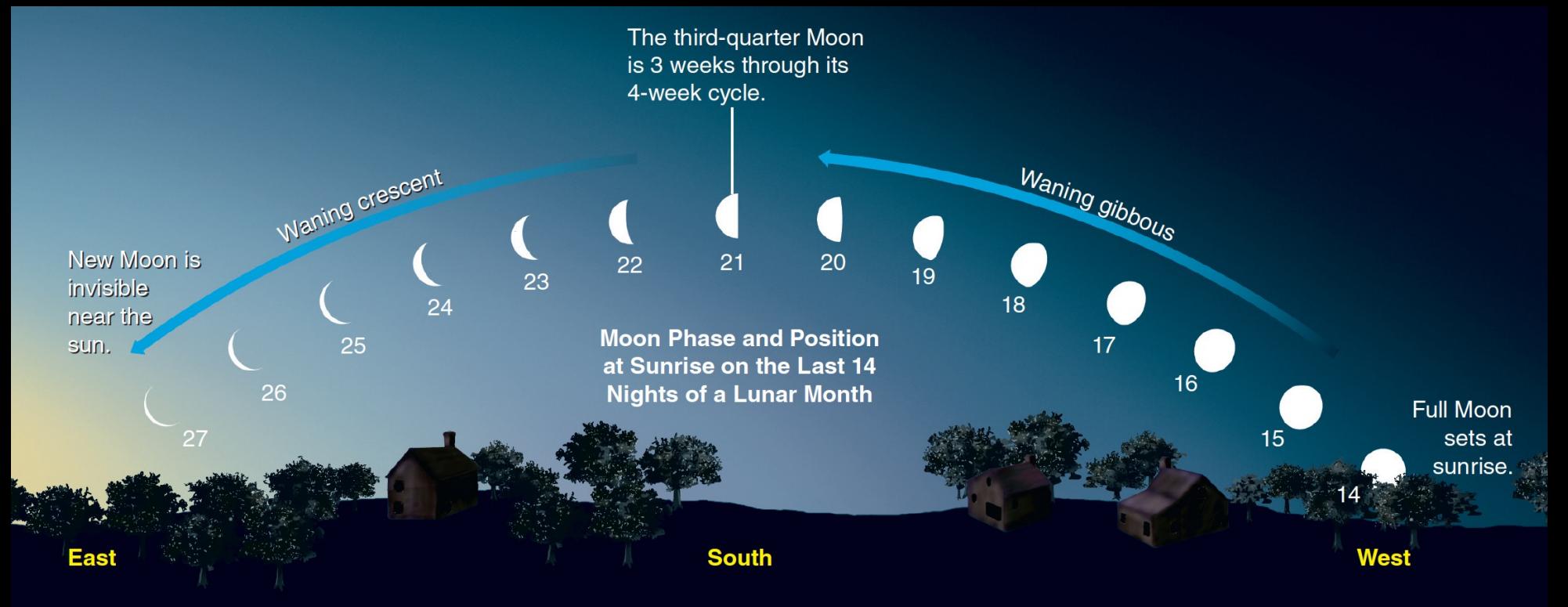
Waxing Phases of the Moon

- From night to night, the moon appears to move from west to east, opposite to the motion within one night! (It **lags almost an hour every night.**)
- The waxing phases of the Moon can be seen primarily in the evening sky.



Waning Phases of the Moon

- As the illuminated portion of the Moon shrinks from the time of full moon to new moon, the Moon is said to “wane,” an old-fashioned word for decrease.

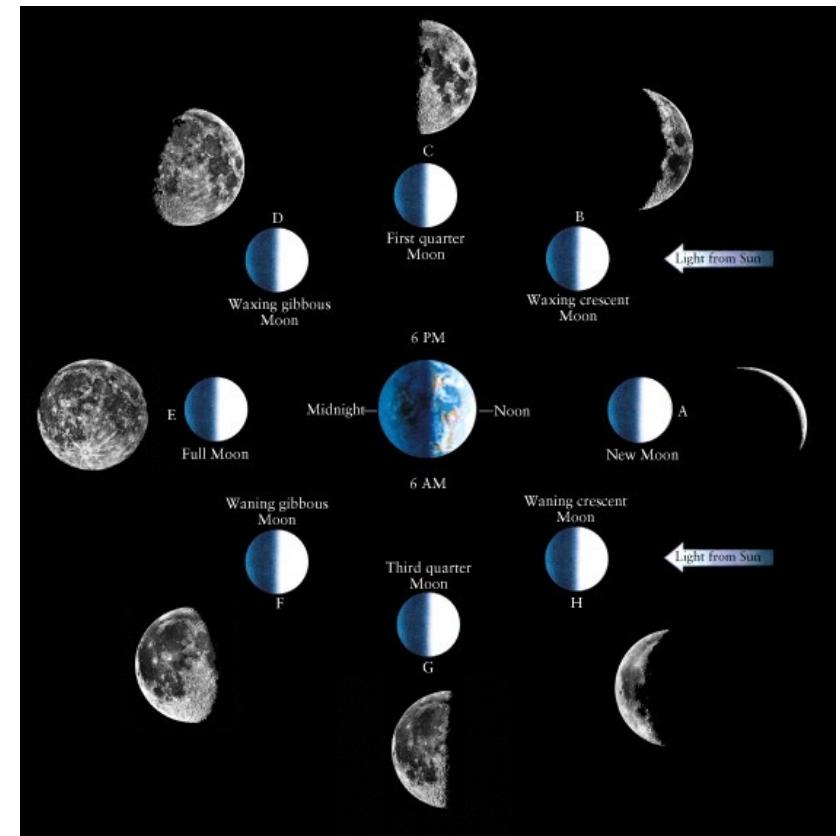


question for you – group work.



Which of the following groups of moon phases can be seen (above the horizon) at 3:00 am?

- A. Third Quarter, Waning Crescent, and Waxing Crescent.
- B. New Moon, First Quarter, and Waxing Gibbous.
- C. Third Quarter, Full Moon, Waning Gibbous.
- D. Waxing Crescent, First Quarter, Waxing Gibbous.
- E. I have no idea.

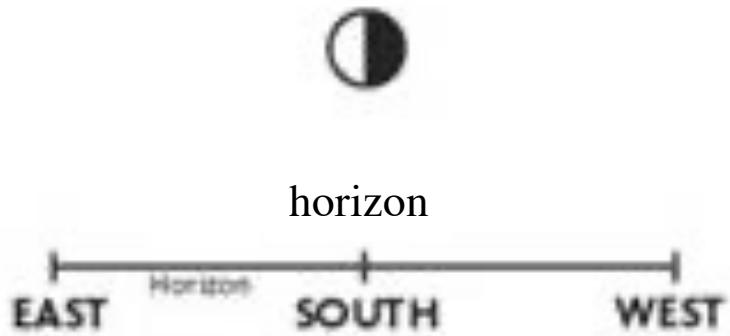


question for you



If the Moon were in the phase shown here, what phase would it be in two weeks later?

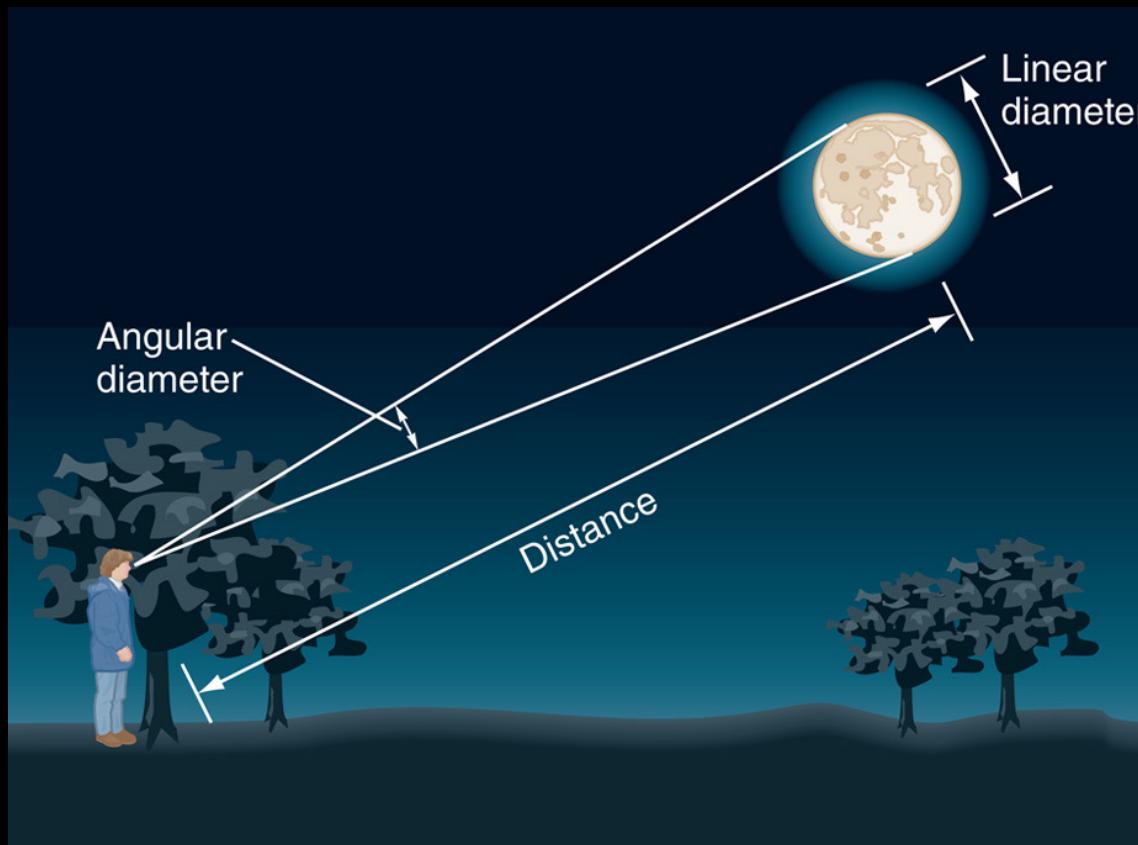
- A. New Moon
- B. First Quarter**
- C. Full Moon
- D. Third Quarter
- E. I have no idea.



Eclipses

Angular Sizes of the Sun and the Moon

- The angular diameter of an object is related to both its linear diameter and its distance.
- The Sun appears approx. as large in the sky (same angular diameter $\approx 0.5^\circ$) as the Moon.



Eclipses

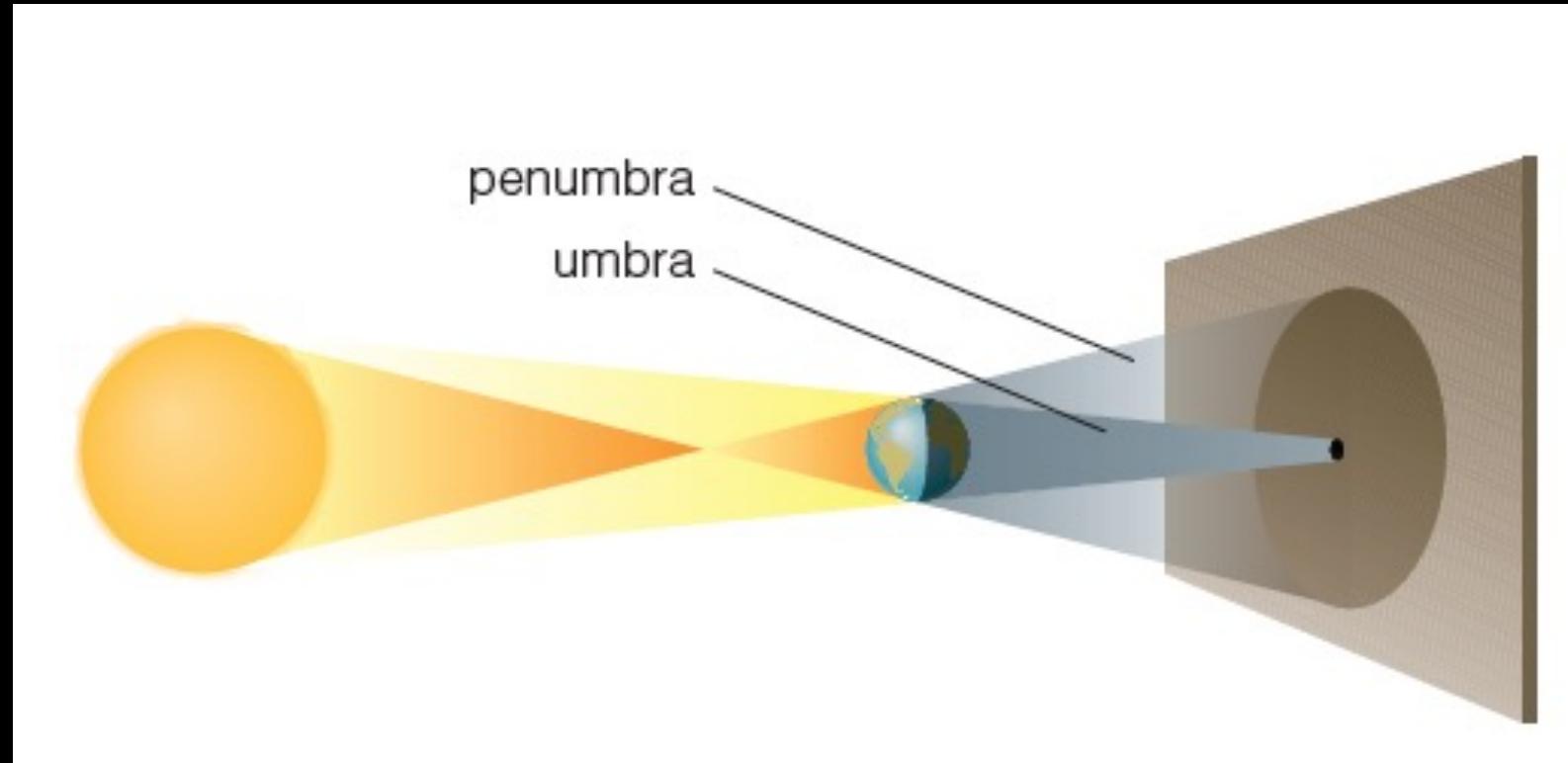
- **Solar eclipses** occur when the new moon blocks Earth's view of the sun.
- **Lunar eclipses** occur when the Moon passes through Earth's shadow, during full moon.



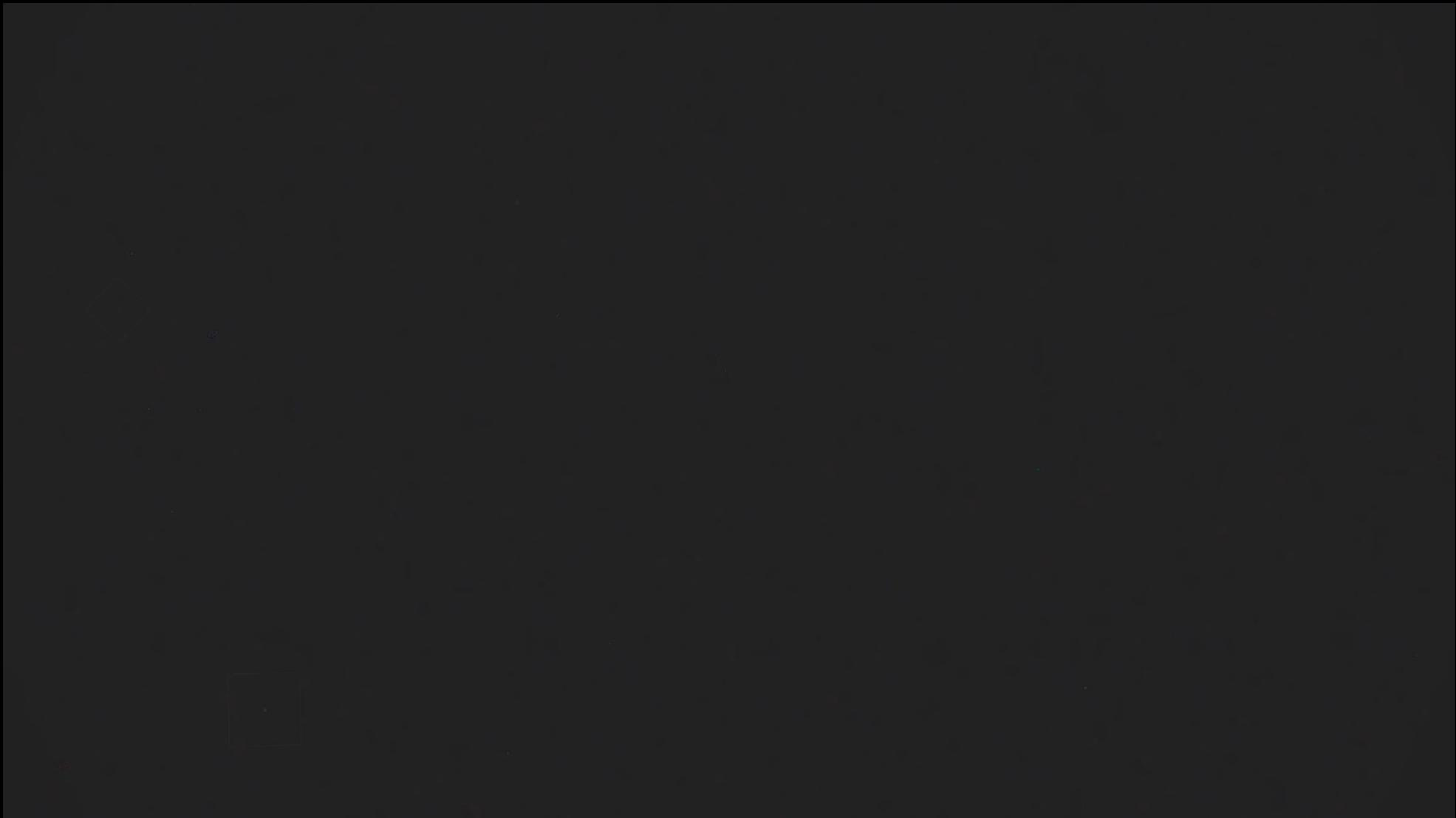
Eclipses

Earth's and Moon's shadows have two regions:

- **Penumbra**: partial shadow (partial eclipse)
- **Umbra**: total shadow (total eclipse)



Lunar and Solar Eclipses



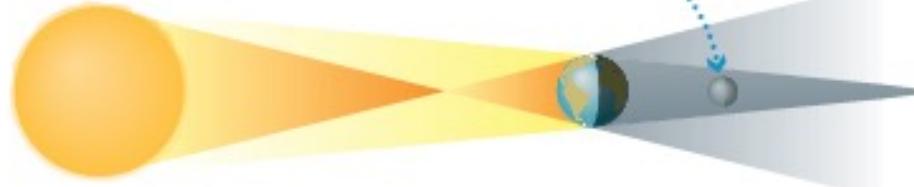
Lunar Eclipses



Image: Vahe Peroomian

Lunar Eclipses

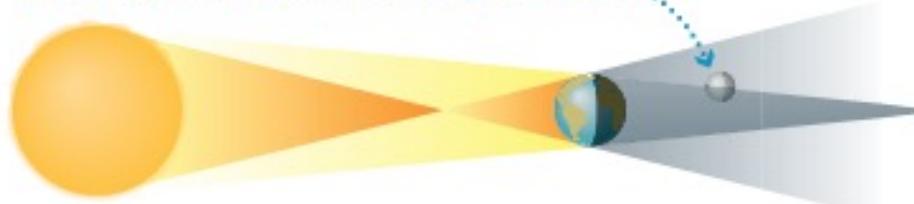
Moon passes entirely through umbra.



Total Lunar Eclipse



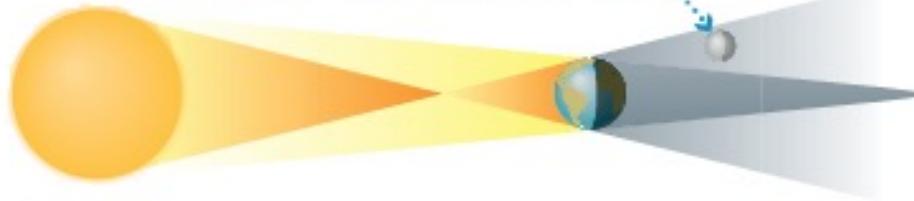
Part of the Moon passes through umbra..



Partial Lunar Eclipse



Moon passes through penumbra.



Penumbral Lunar Eclipse



Solar Eclipses

A dramatic photograph of a solar eclipse. A person stands on a dark, craggy rock formation, silhouetted against the intense light of the sun. The sun is a large, bright circle, partially obscured by the dark silhouette of the Earth's horizon. The surrounding sky is a deep, dark gray.

next image

MICHAEL SHAINBLUM

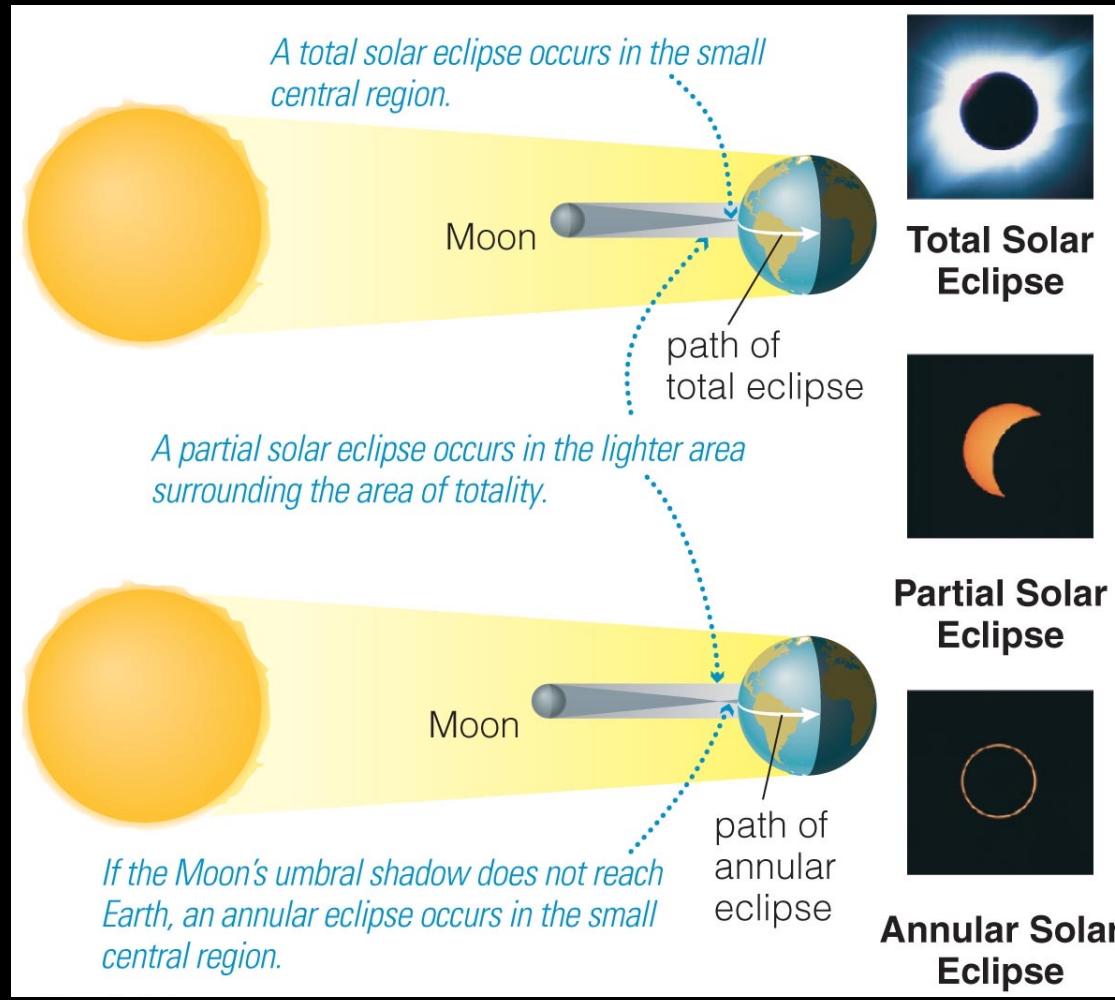
Solar Eclipses



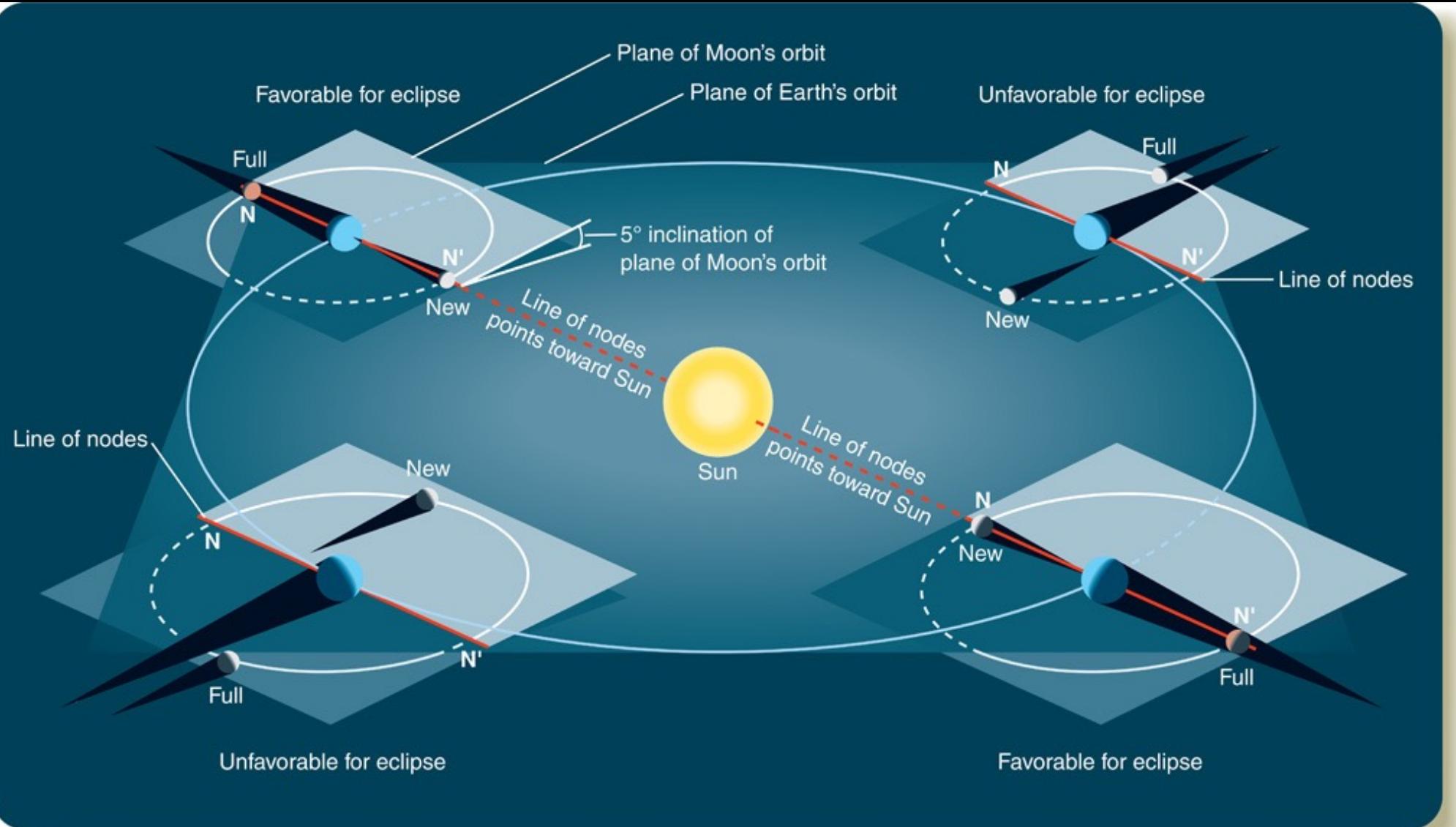
Image: Vahe Peroomian

Solar Eclipses

Moon's distance from Earth, and therefore its angular size, varies. When the Moon is very far from Earth, it cannot completely cover the solar disk.



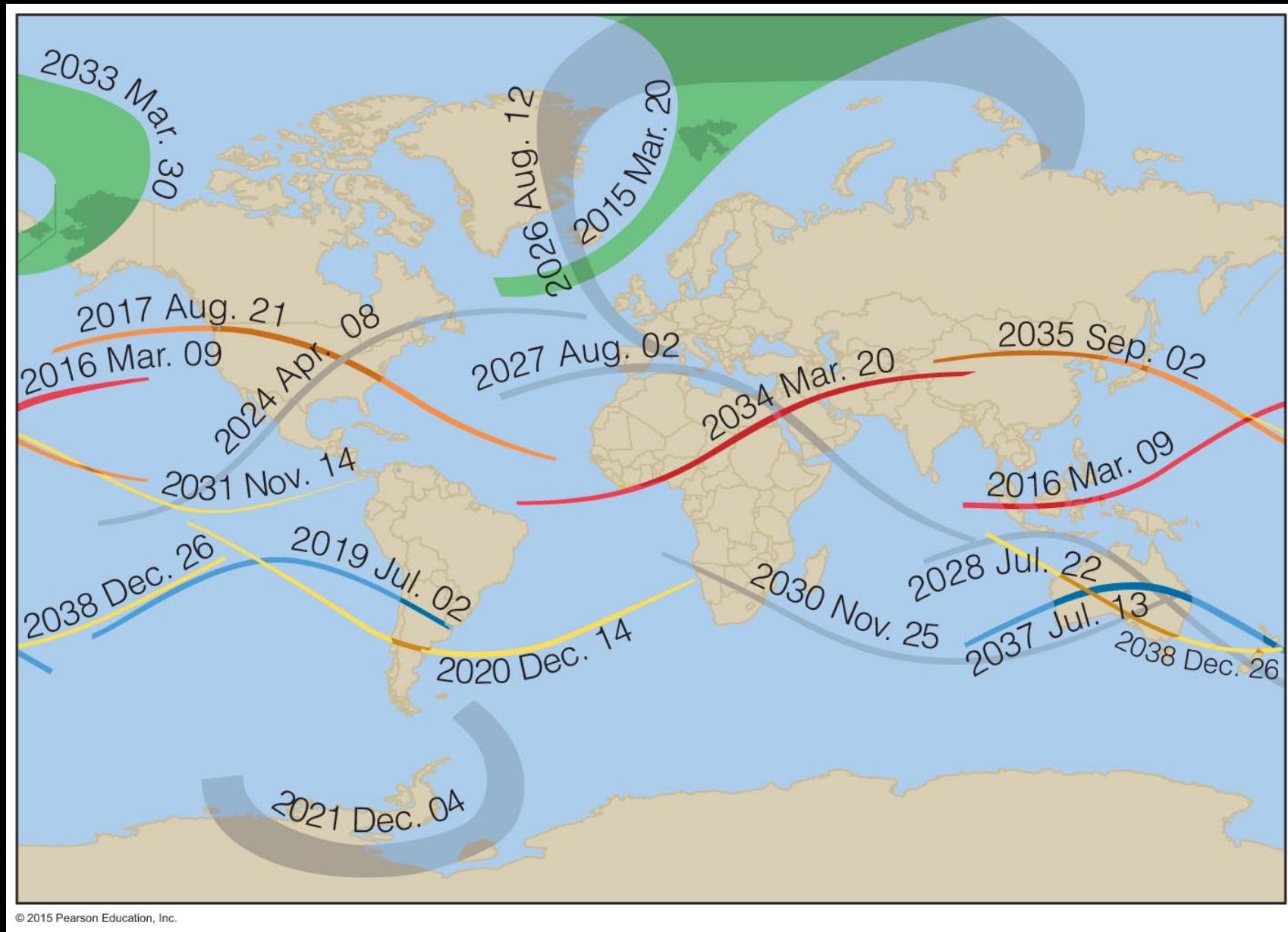
Lunar and Solar Eclipses



Why don't eclipses happen during all new and full moons?

- Lunar orbit is tilted with respect to ecliptic plane, and crosses it at two points, called the **nodes**.
- Eclipses occur when the nodes coincide with new or full moon. This occurs approximately twice a year, during what are called **eclipse seasons**, which last several weeks.
- The nodes in the lunar orbit precess, so that eclipse seasons occur 173 days apart.
- The **Saros cycle** is the 18-year, 11 1/3 day recurring eclipse cycle.

Next Solar Eclipse?



question for you



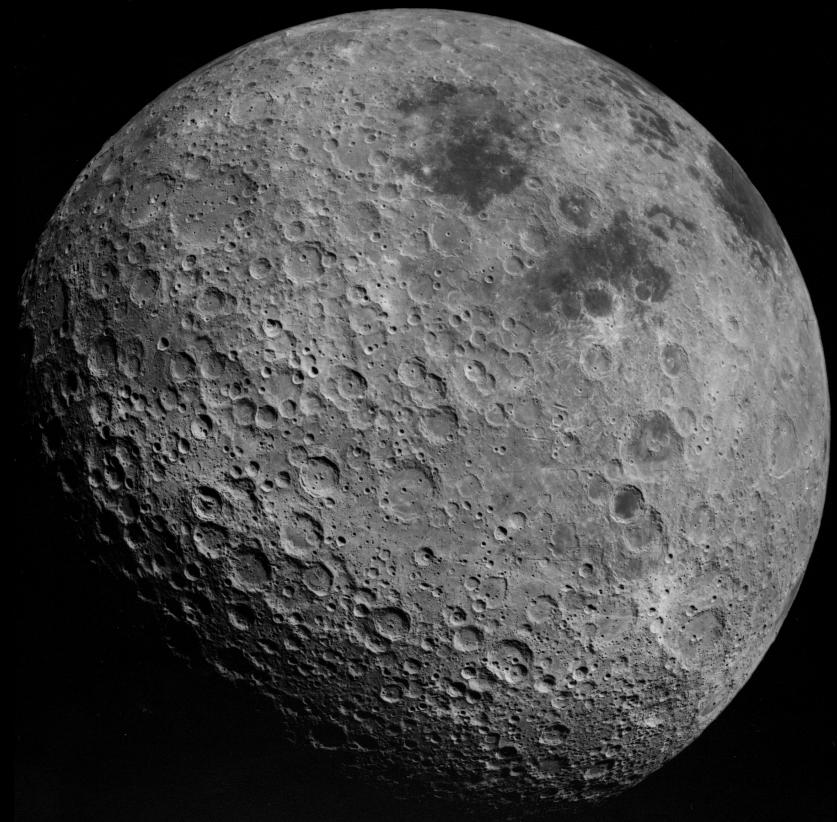
When the Moon is in the full phase and is directly in line with the Earth and the Sun , you get a lunar eclipse.

When the Moon is in the new phase and is directly in line with the Earth and the Sun , you get a solar eclipse.

Rotation

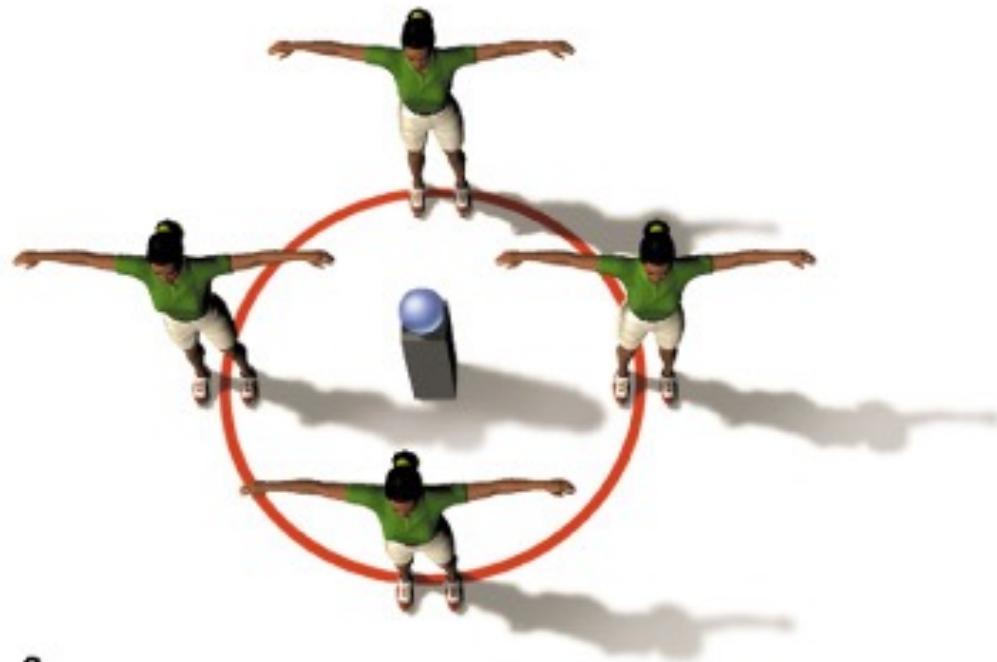
Rotation of the Moon

The near (left) and far (right) side of the Moon.
The far side is never visible from Earth. Why?



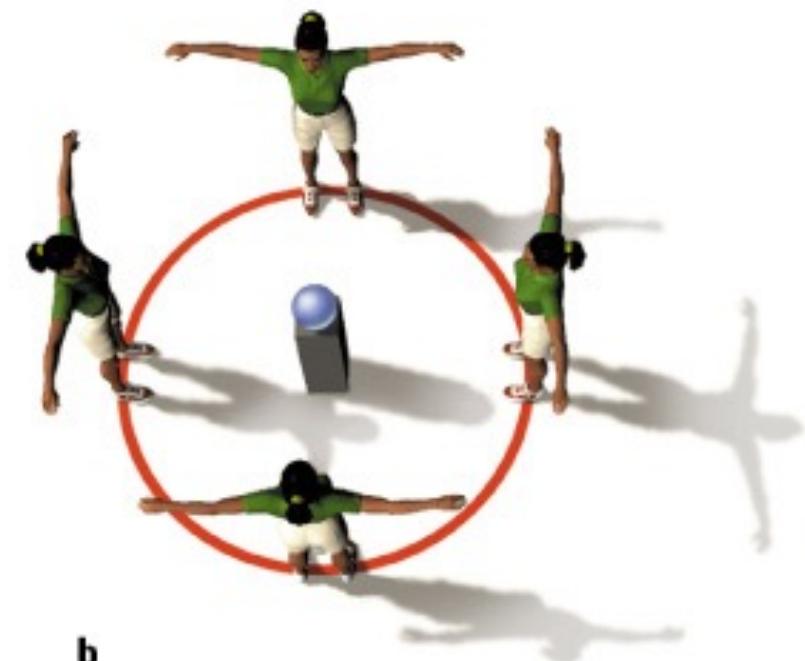
Synchronous Rotation

The Moon executes one rotation around its axis during each revolution around the planet.



a

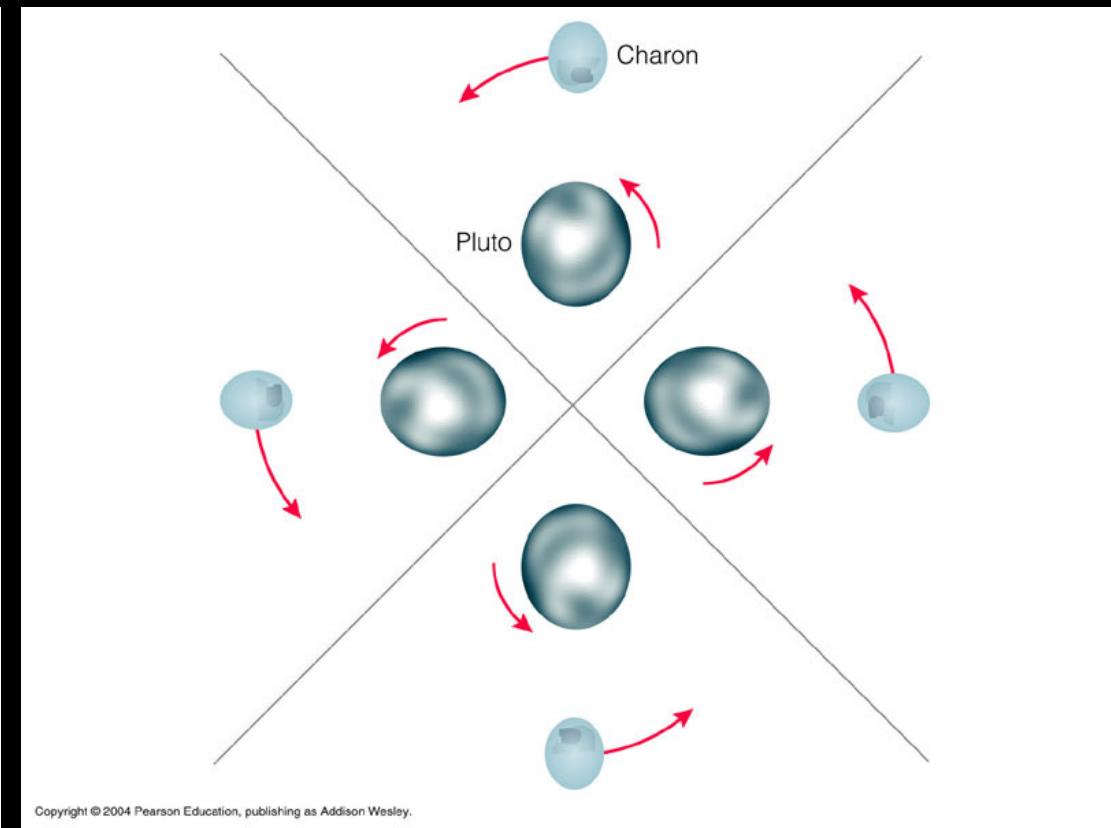
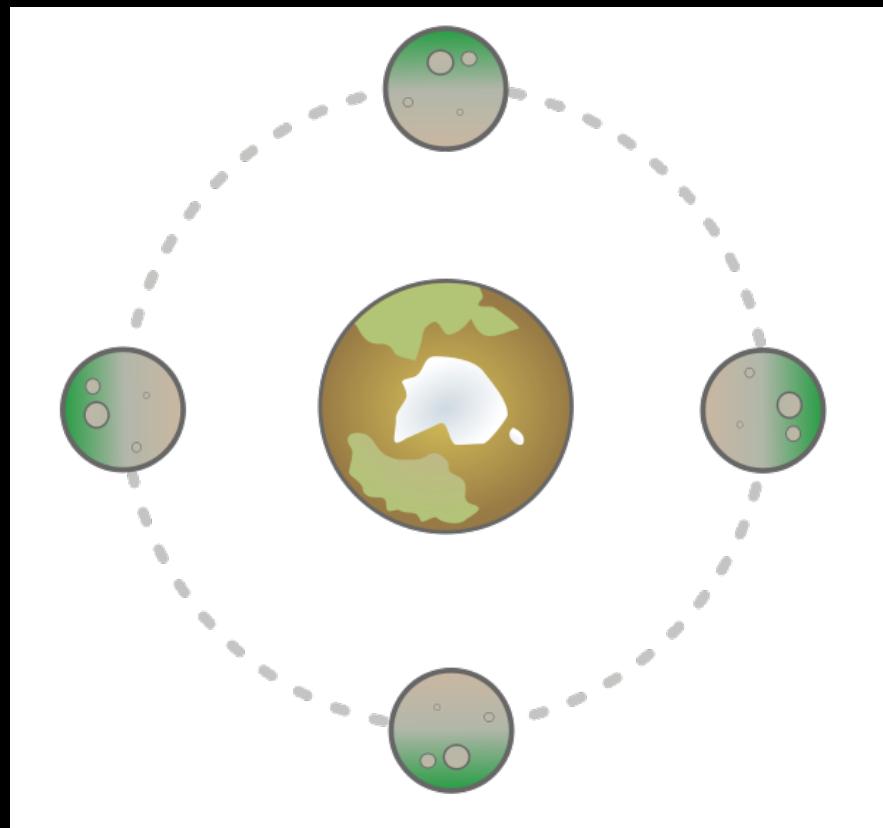
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b

Tidal locking

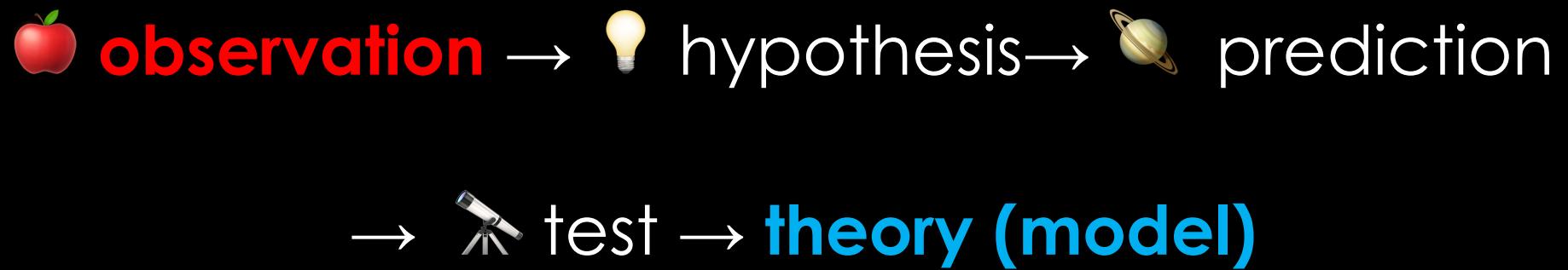
Synchronous rotation is a consequence of **tidal locking** and means that the Moon always keeps the same face toward its parent planet.



Scientific method

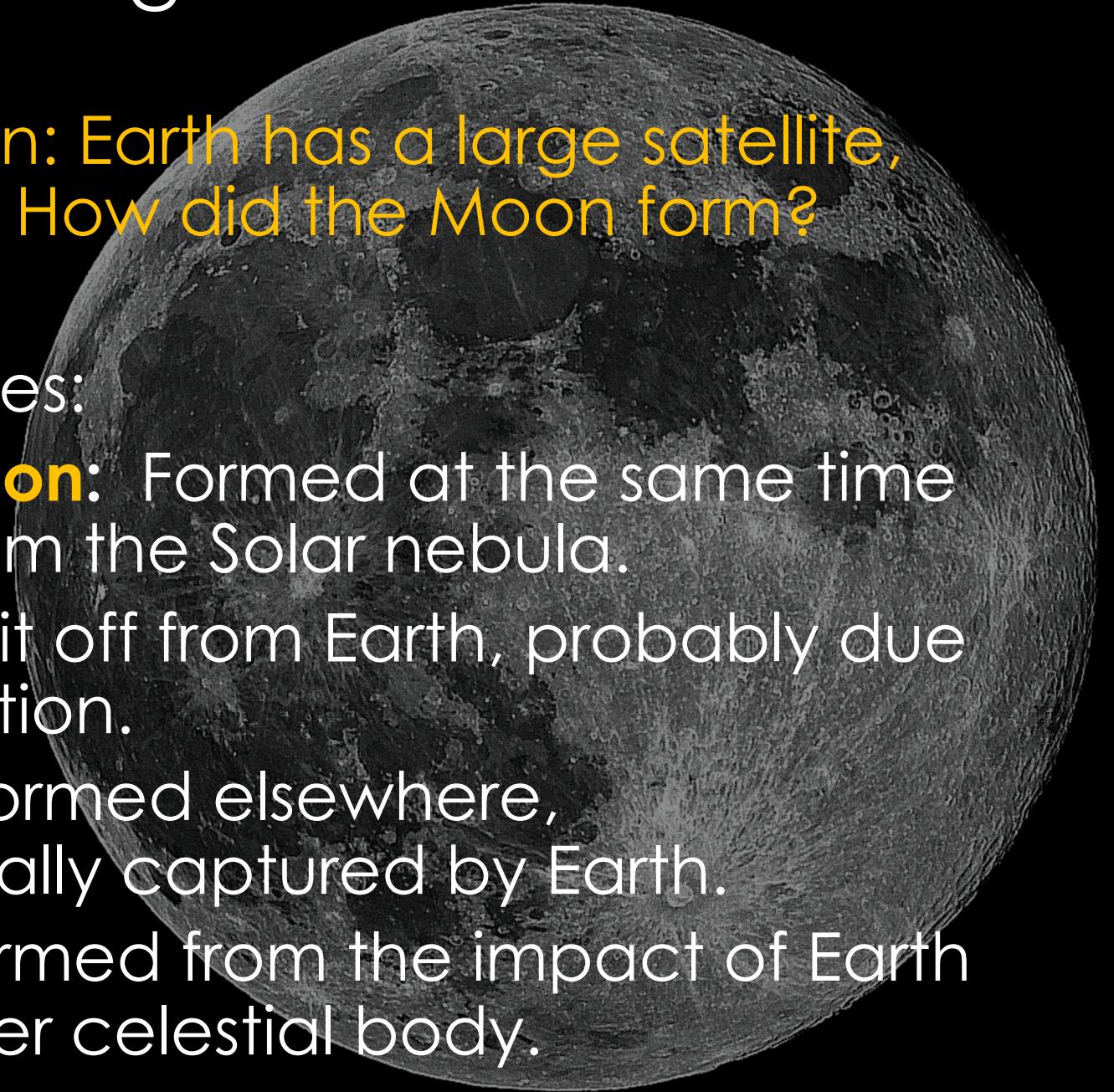
The Scientific Method

Repeated use of objective, rigorous, and systematic procedures by which what we think about reality is then tested against what we observe, and what we observe is examined in the light of what we know.



Example: Origin of Earth's Moon

- Observation: Earth has a large satellite, the Moon. How did the Moon form?
- 4 hypotheses:
 - Co-Accretion:** Formed at the same time as Earth from the Solar nebula.
 - Fission:** Split off from Earth, probably due to fast rotation.
 - Capture:** Formed elsewhere, gravitationally captured by Earth.
 - Impact:** Formed from the impact of Earth and another celestial body.



Co-Accretion

- Prediction:

Rocky planets and moons formed during accretion have iron cores, so the Moon should too, if it formed the same way.

- Test:

The Moon does not have a large iron core. This hypothesis is falsified.



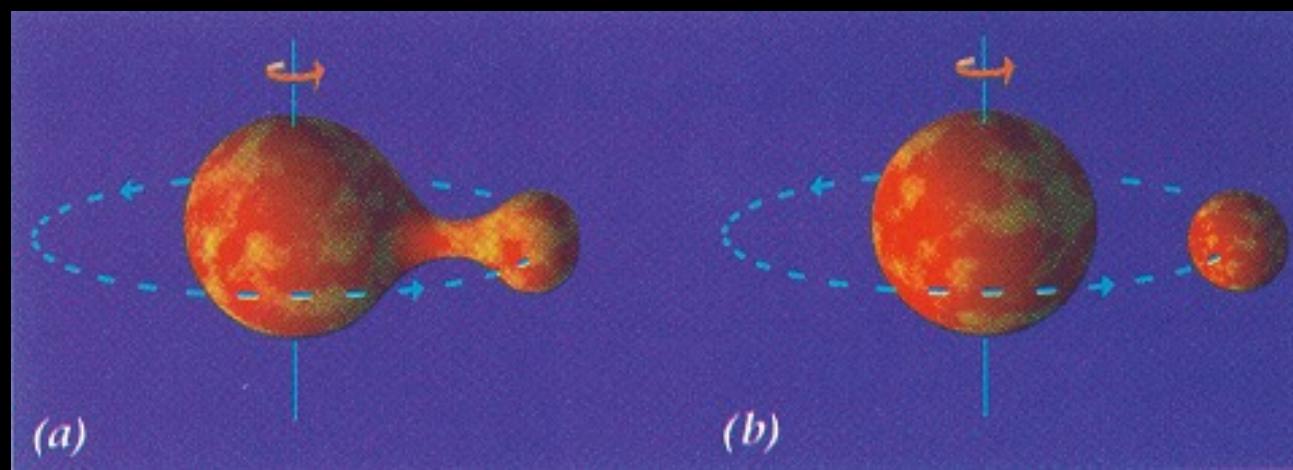
Fission

- Prediction:

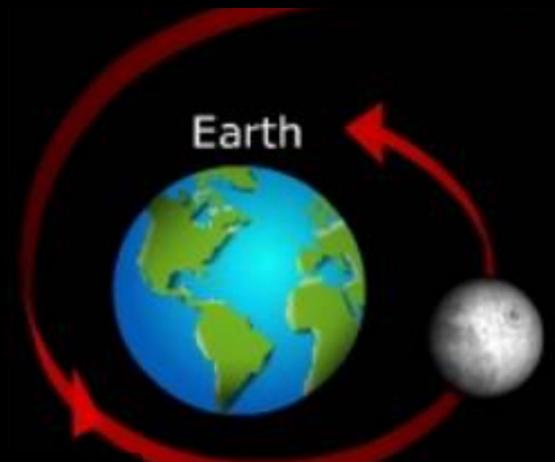
The Earth would was spinning very fast and a piece of it to broke off to form the Moon.

- Test:

This would have broken Earth into pieces. Also, no reason for Earth to spin so fast, unlike any other planet. This hypothesis is falsified.



Capture



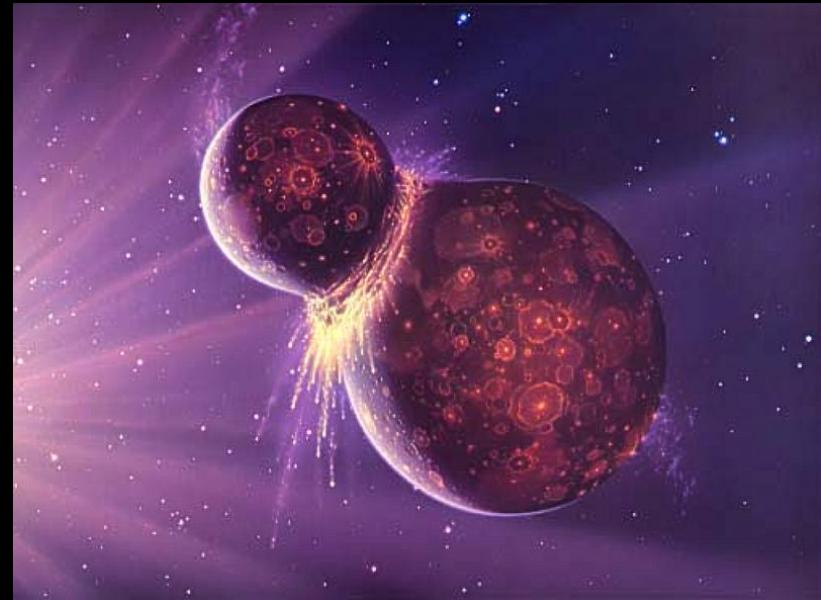
- Prediction:

If Moon is a captured body that formed elsewhere, the composition of Moon's crust should be different from that on Earth and Mars and the Asteroid Belt.

- Test:

The compositions are similar in isotope content. Thus, the Moon could not have formed far away and then later captured by Earth's gravity. Also, it's hard for something as small as the Earth to capture something $\frac{1}{4}$ its size! This hypothesis is falsified.

Giant Impact



- Prediction:

If the Moon broke off the Earth's crust/mantle due to a giant impact, after the Earth differentiated, it will have the same isotope content as the Earth, and will not have a large iron core.

- Test:

Because of these match observations and because of the lack of evidence to the contrary, the “impact model” (or impact theory) is now widely accepted as the most probable explanation for the origin of the Moon.

How convinced are you that the impact theory is correct?

What did we learn in Chapter 3?

- The Moon is tidally locked in synchronous rotation around the Earth.
- Moon phases are caused by relative positions of Sun, Earth, and Moon.
- A lunar eclipse occurs when the Moon moves into Earth's shadow (only occurs during full moon).
- A solar eclipse occurs when the Moon momentarily blocks our view of the Sun (only occurs during new moon).
- The Saros cycle is the 18-year, 11 1/3 day recurring eclipse cycle.
- The Moon was formed by a giant impact early in the Solar System's history.