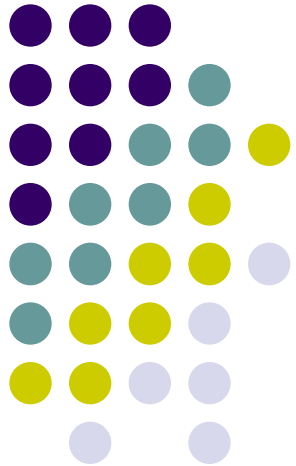
The Moon



Orbit

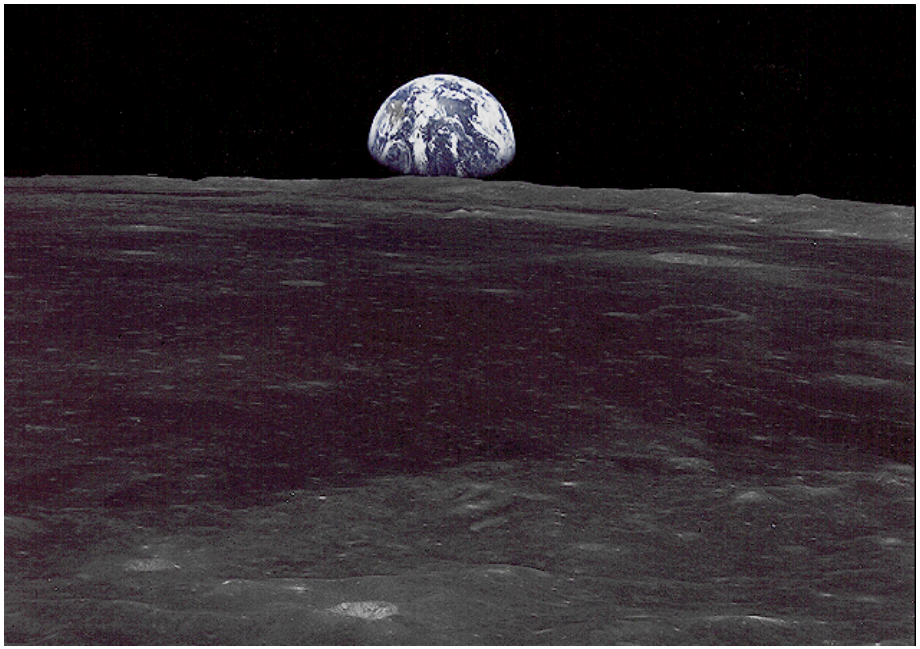
- Parallax methods can provide us with quite accurate measurements of the distance to the Moon
  - Earth's diameter is used as a baseline
- Radar and laser ranging yield more accurate distances
  - The Moon is much closer than any of the planets, and the radar echo bounced off the Moon's surface is strong
  - A radio telescope receives the echo after about a 2.56-second wait
  - Dividing this time by two (to account for the round-trip taken by the signal) and multiplying it by the speed of light (300,000 km/s) gives us a mean distance of 384,000 km (239,000 miles)

Physical Properties

- The Moon's radius is about 1100 miles
  - Roughly one-fourth that of Earth
- The mass of the Moon is 7.3×10^{22} kg
  - Approximately 1/80 the mass of Earth
  - Suggests that the Moon contains fewer heavy elements (such as iron) than Earth
- The force of gravity on the lunar surface is only about one-sixth that on Earth
  - An astronaut weighing 180 lb on Earth would weigh a mere 30 lb on the Moon

Atmosphere

- Astronomers have never observed any appreciable atmosphere on the Moon either spectroscopically from Earth or during close approaches by space
- This is a direct consequence of the weak gravitational field
- Massive object has a better chance of retaining an atmosphere, because the more massive an object, the larger the speed needed for atoms or molecules to escape
  - The Moon's escape speed is only 2.4 km/s, compared with 11.2 km/s for Earth
- Any primary atmosphere this world had initially, or secondary atmosphere that appeared later, are gone forever
- The Moon has no protection against the harsh environment of interplanetary space

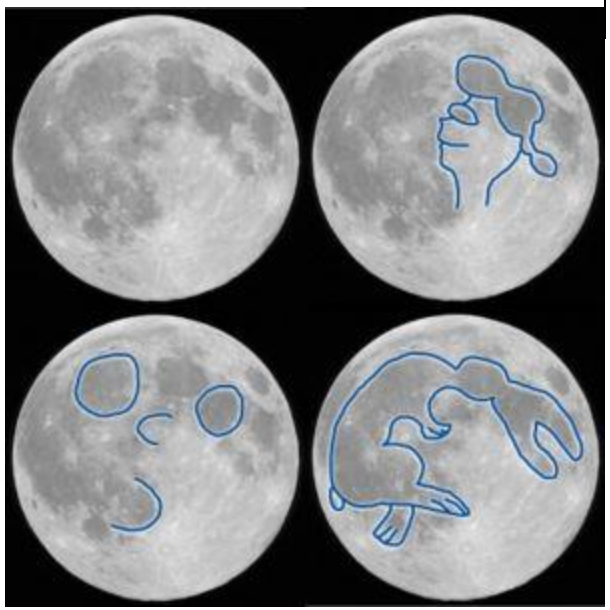


Temperature

- Lacking the moderating influence of an atmosphere, the Moon experiences wide variations in surface temperature
- Noontime temperatures at the Moon's equator can reach 400 K (260 degrees F), well above the boiling point of water
- At night or in the shade, temperatures fall to about 100 K (-280 degrees F), well below water's freezing point

Terrain

- The first observers to point their telescopes at the Moon noted large dark areas, resembling (they thought) Earth's oceans
- They also saw light-colored areas resembling the continents
- The light and dark surface features are also evident to the naked eye, creating the face of the familiar "man in the moon"



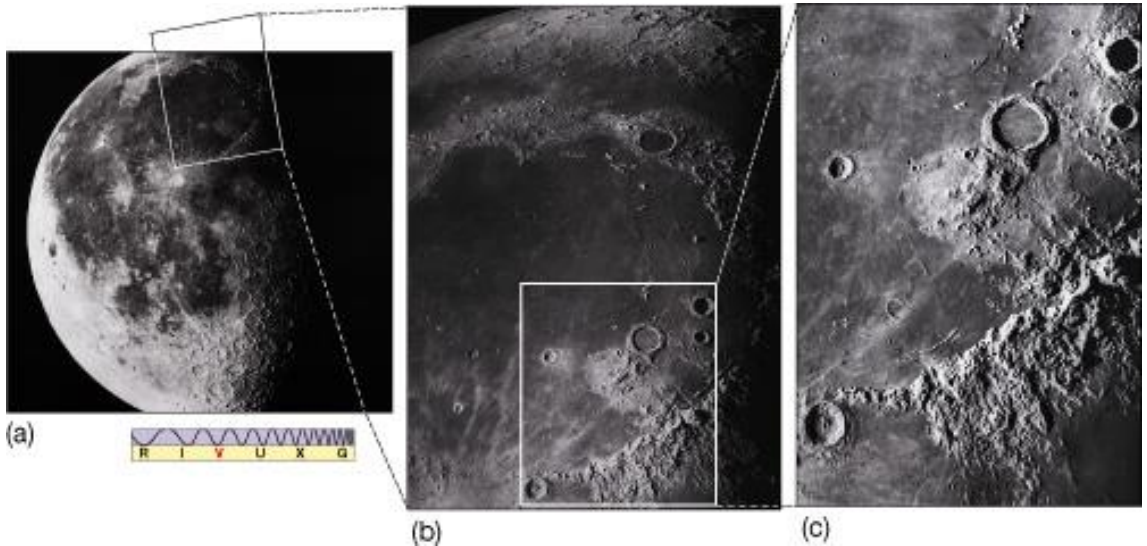
Maria and Highlands

- Maria-the dark regions that are extensive flat areas that resulted from lava flows during a much earlier period of the Moon's evolution
  - Derived from the Latin word meaning "seas"
  - There are 14 maria, all roughly circular
  - The largest of them (Mare Imbrium) is about 680 miles in diameter
- Lunar highlands-the lighter areas elevated several kilometers above the maria

Craters

- Most craters apparently formed eons ago primarily as the result of meteoritic impact
- Craters are found everywhere on the Moon's surface
  - They are much more prevalent in the highlands
  - They come in all sizes
    - The largest are hundreds of kilometers in diameter
    - The smallest are microscopic


R I V U X G


(a)
R I V U X G
(b)
(c)

Highlands vs. Maria

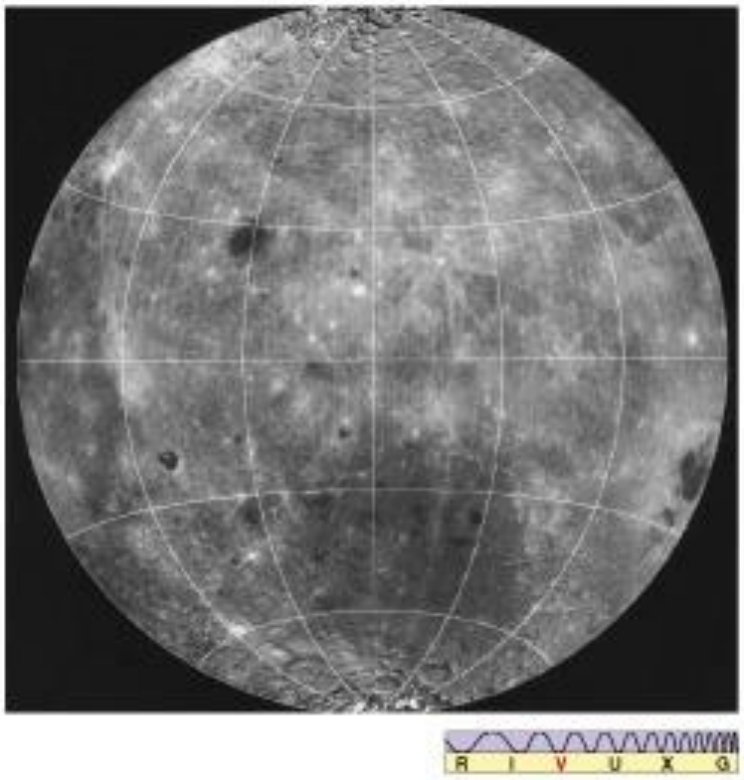
- Geologists have identified important differences in both composition and age between the highlands and the maria
- The highlands are made largely of rocks rich in aluminum, making them lighter in color and lower in density
- The maria's basaltic matter contains more iron, giving it a darker color and greater density
- The highlands represent the Moon's crust, while the maria are made of mantle material
- Geologists believe that Maria rock arose on the Moon through the upwelling of molten material through the crust
- Radioactive dating indicates ages of 4 to 4.4 billion years for highland rocks, and from 3.2 to 3.9 billion years for those from the maria

Features

- All the Moon's significant surface features have names
- The 14 maria bear fanciful Latin names—Mare Imbrium ("Sea of Showers"), Mare Nubium ("Sea of Clouds"), Mare Nectaris ("Sea of Nectar"), etc.
- Most mountain ranges in the highlands bear the names of terrestrial mountain ranges—the Alps, the Carpathians, the Apennines, the Pyrenees, and so on
- Most of the craters are named after great scientists or philosophers, such as Plato, Aristotle, Eratosthenes, and Copernicus

Far Side

- The Moon has a “near” side, which is always visible from Earth, and a “far” side, which never is
- When the far side of the Moon was mapped, first by Soviet and later by U.S. spacecraft no major maria were found there
- The lunar far side is composed almost entirely of highlands

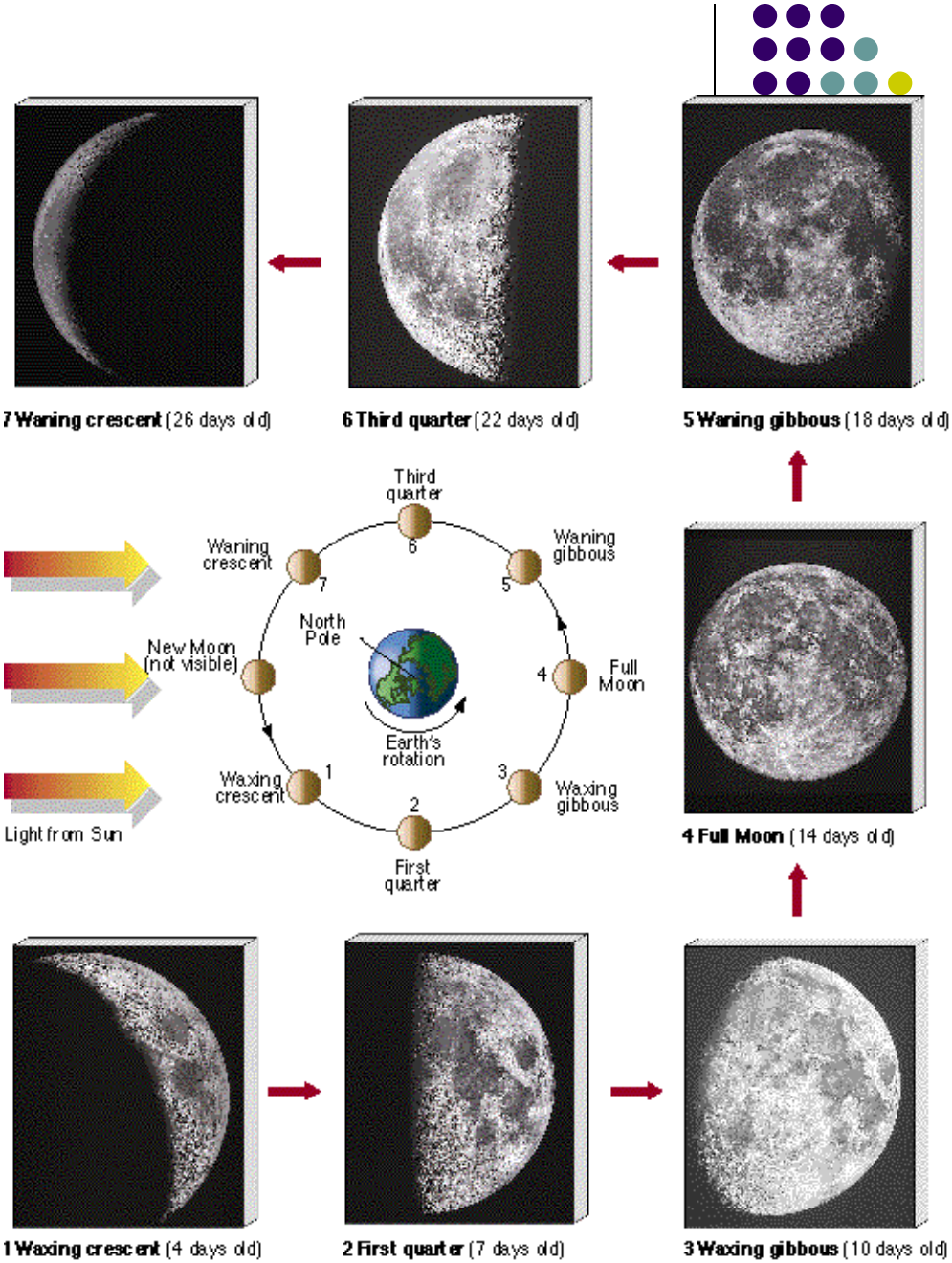


Rotation

- The Moon's rotation period is precisely equal to its period of revolution about Earth—27.3 days—so the Moon keeps the same side facing Earth at all times
  - Synchronous orbit-condition, in which the spin of one body is precisely equal to its revolution around another body
- To an astronaut standing on the Moon's near-side surface, Earth would appear almost stationary in the sky

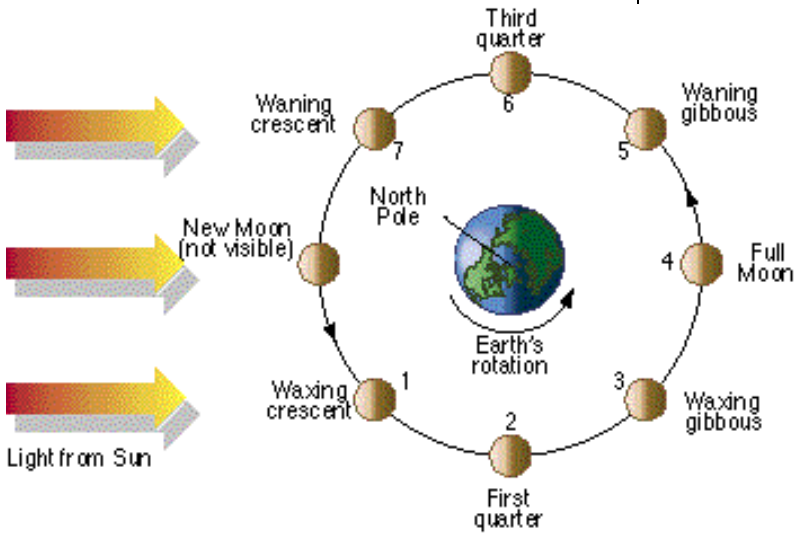
Lunar Phases

- Phase-regular cycle of change
- Takes about 29 days to complete
  - New moon
  - Crescent moon
  - 1st Quarter moon
  - Gibbous phase
  - Full moon
  - Gibbous phase
  - 3rd Quarter moon
  - Crescent Moon
  - New Moon
- Wax-growing Moon
- Wane-shrinking Moon



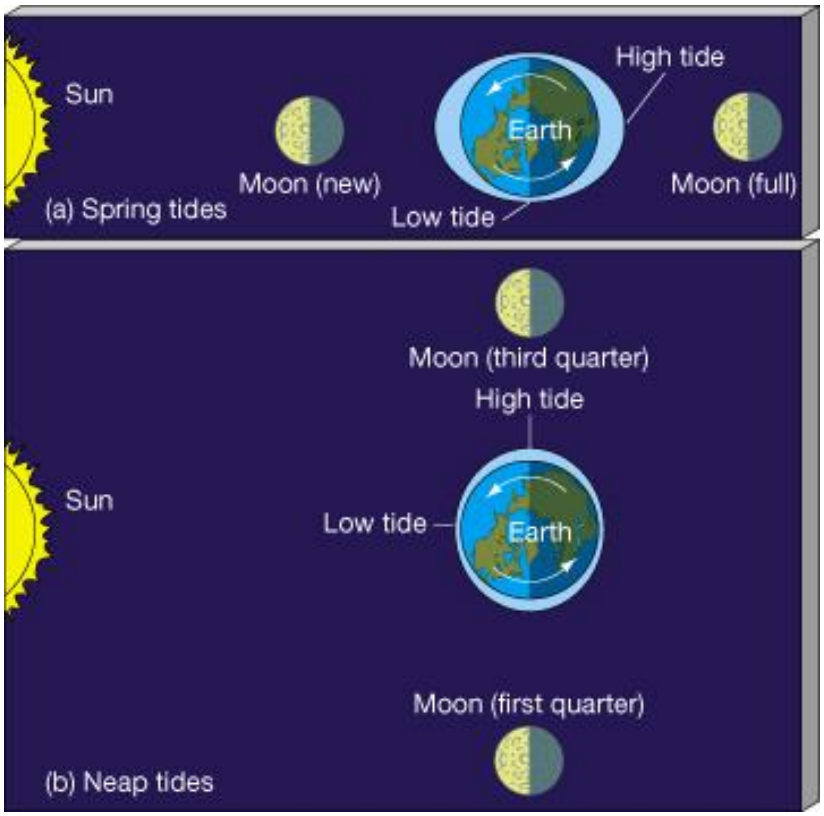
Why Don't We Always See a Full Moon?

- Moon emits no light of its own
- Shines by reflected sunlight
- Half of the Moon's surface is illuminated by the Sun at any instant
- Not all the Moon's sunlit face can be seen because of the Moon's position with the Earth and the Sun



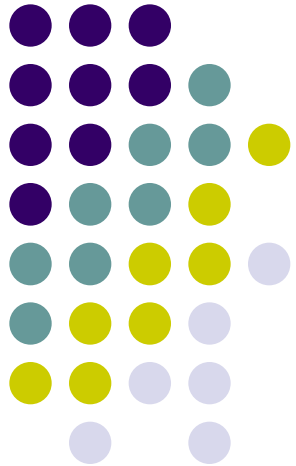
- When Moon is full – see entire “daylit” face because Sun and the Moon are in opposite directions from Earth in the sky
- New Moon – Moon and Sun are in almost the same part of the sky and the sunlit side of the Moon is oriented away from us

Tides

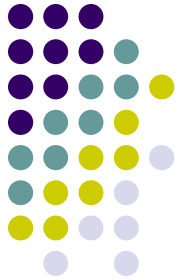


- At most coastal locations on Earth, there are two low tides and two high tides each day
- The tides are a direct result of the gravitational influence of the Moon and the Sun on Earth

Moon Formation



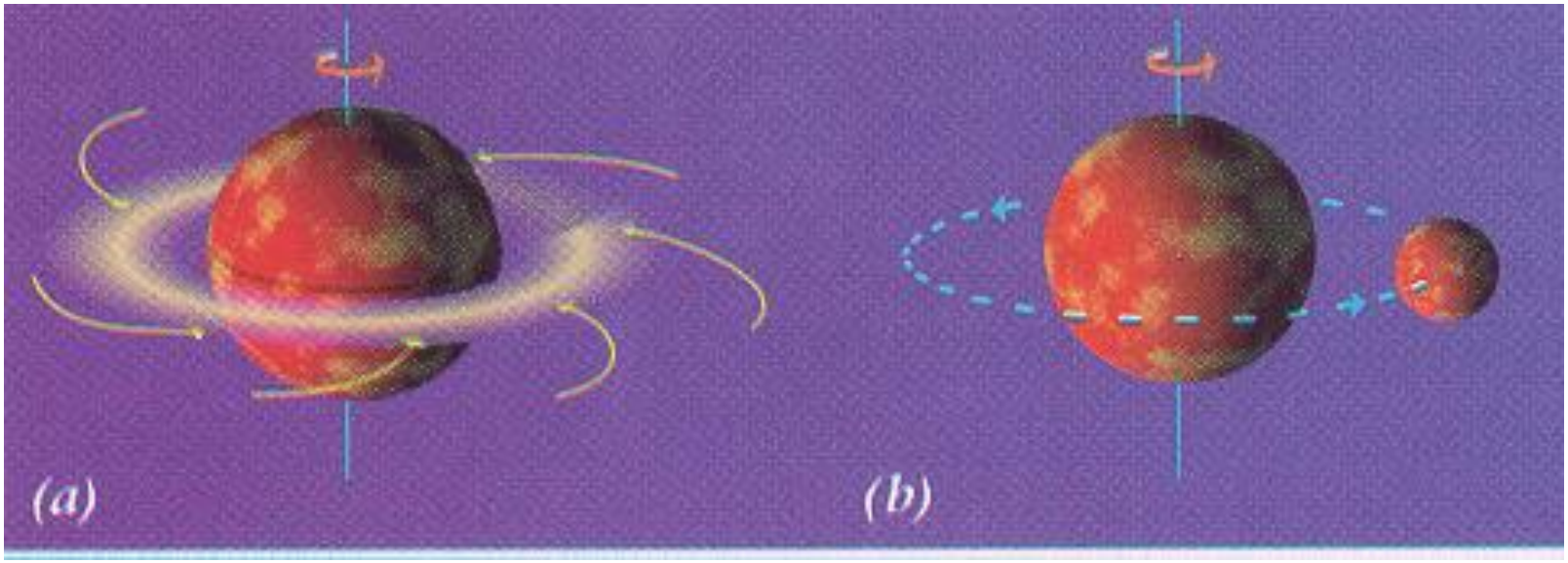
Sister / Co-creation / Condesation Theory



- The Moon and the Earth condensed together from the original nebula that formed the Solar System.
- The Moon differs in both density and composition from Earth, making it hard to understand how both could have originated from the same pre-planetary material

Accretion Theory

- - The Earth accretes planetesimals in early solar system to form Moon.

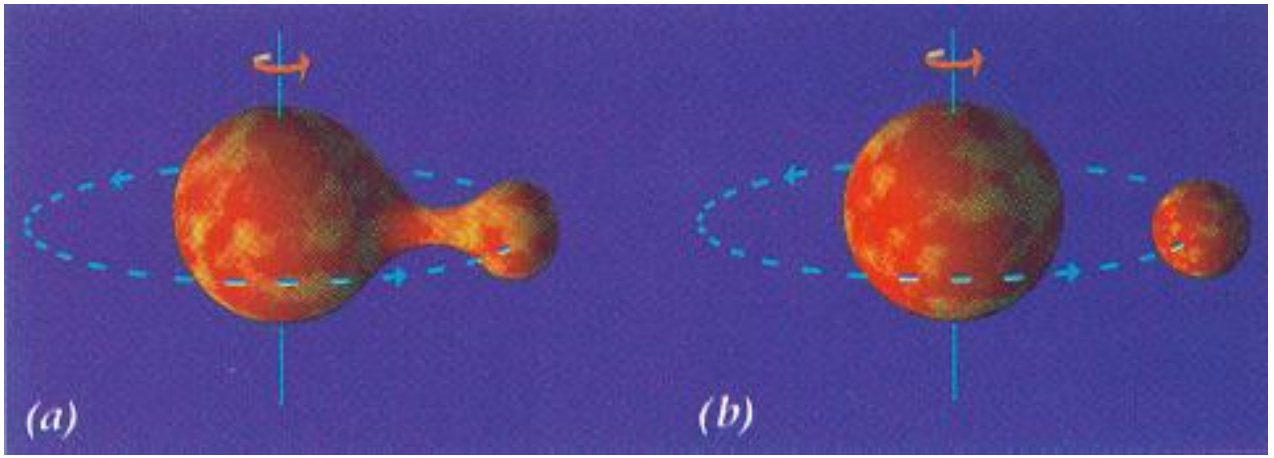


Pros and Cons

- **Pros:** Lots of material around in the early solar system to accrete
- **Cons:**
  - Why would the Earth and Moon have different compositions (ie why is the moon deficient in Iron)?
  - Earth-Moon system has too much angular momentum compared to other planets.

Fission Theory

- The Moon was once part of the Earth and somehow separated from the Earth early in the history of the Solar System.
- Earth could possibly have been spinning so fast that it ejected an object as large as our Moon
- The present Pacific Ocean basin is the most popular site for the part of the Earth from which the Moon came.



Pros and Cons

- **Pros:** Density of Moon similar to that of the outer layers of the Earth
- **Cons:**
  - Moon should be orbiting along Earth's equator; it's not.
  - Composition of Moon rocks dissimilar to that of the Earth's surface.
  - Earth would have to have been spinning extremely fast (HW problem).

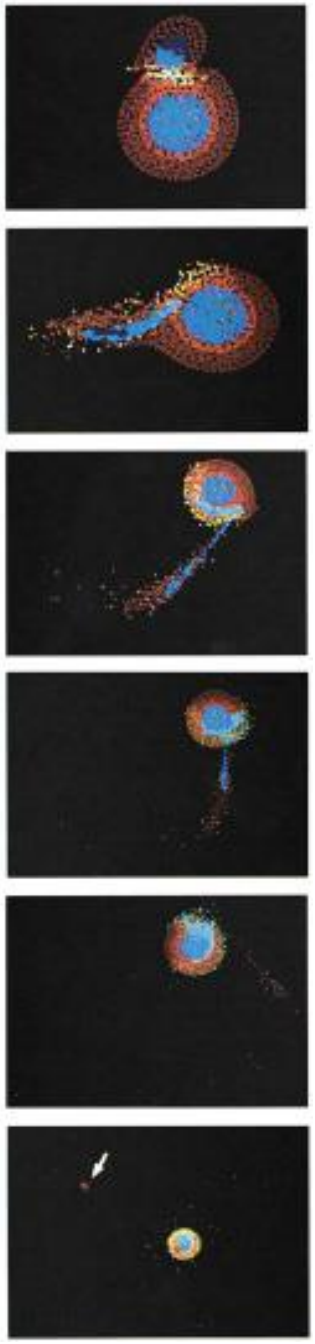
Capture Theory

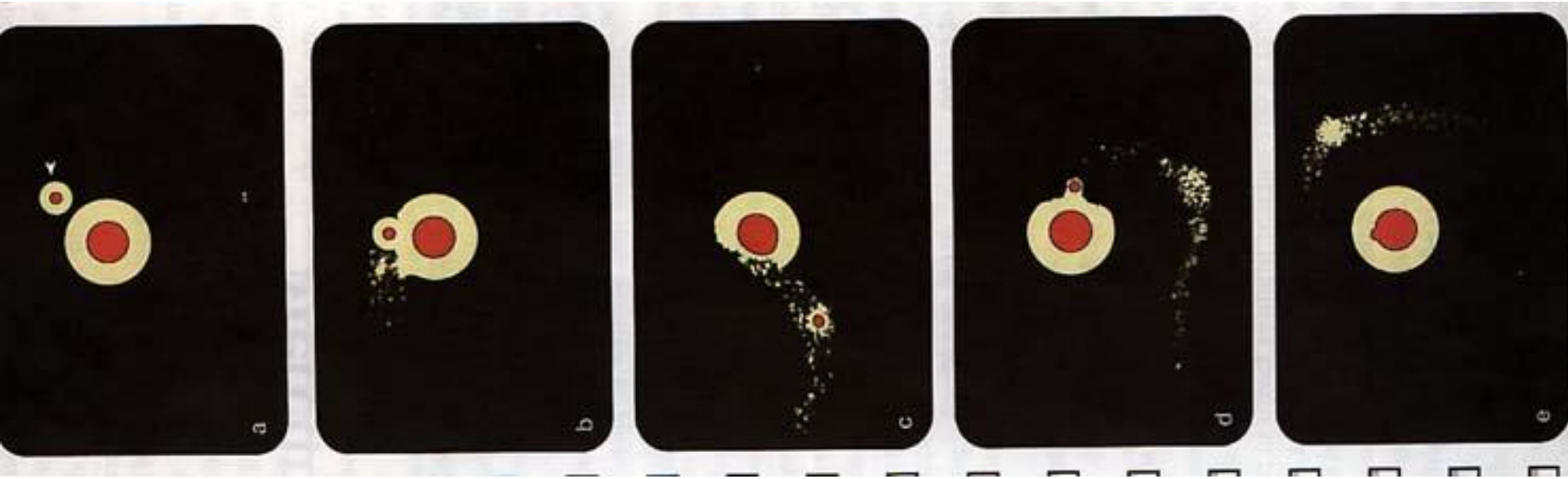
- the Moon formed elsewhere passed close to Earth and was captured

  - **Pros:** well, it's not impossible
  - **Cons:**
    - it's very unlikely
    - The objection to this theory is that the Moon’s capture would be an extraordinarily difficult event because the mass of our Moon is so large relative to that of Earth

Impact Theory

- Today, many astronomers favor a hybrid of the capture and fission themes
- Postulates a collision by a large, Mars-sized object with a youthful and molten Earth
- The matter dislodged from our planet then reassembled to form the Moon




a
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Pros and Cons

- **Pros:**
  - Collisions happen (but this is a whopper: Mars sized or bigger!)
  - Explains lack of volatiles in Moon
  - Explains lack of an Iron core
  - Simulations confirm the possibility Animation
  - Bonus: explains tip of the Earth's axis!
- **Cons:**
  - To get material past the Earth's Roche limit, the impactor needs more angular momentum than is now in the Earth-Moon system.
  - Why just one moon?

Moon Hoax