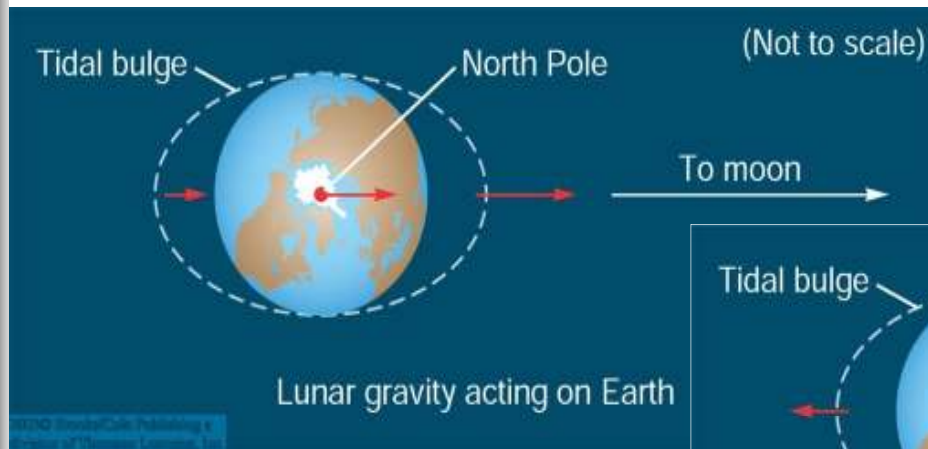


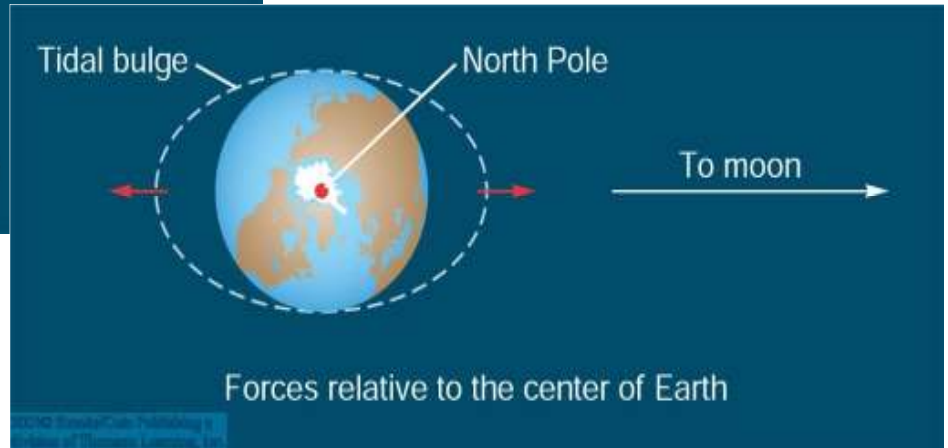
The Tides

Caused by the difference of the Moon's gravitational attraction on the water on Earth



Forces are balanced at the center of the Earth

Excess centrifugal force pushes water away from the moon on the far side

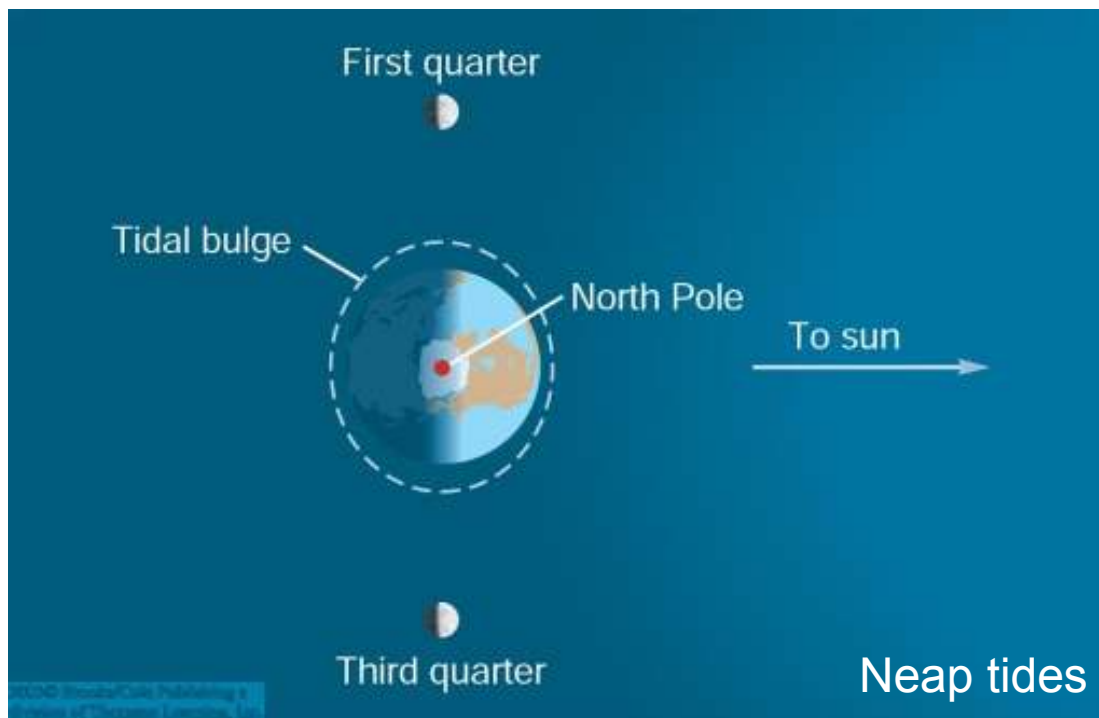


→ 2 tidal maxima
→ 12-hour cycle

Spring and Neap Tides



The Sun is also producing tidal effects, about half as strong as the Moon.



- Near Full and New Moon, those two effects add up to cause *spring tides*.

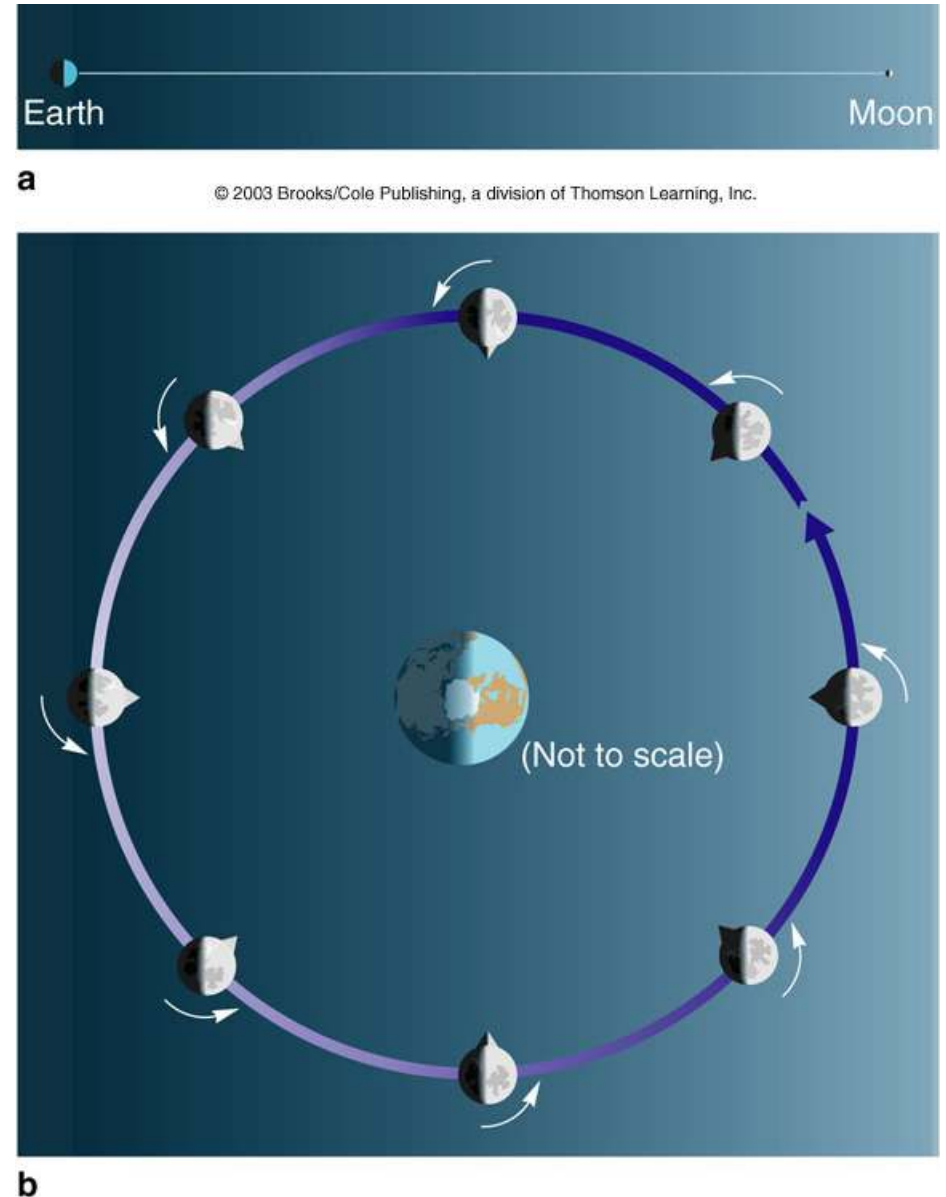
- Near first and third quarter, the two effects work at a right angle, causing *neap tides*.

The Tidally-Locked Orbit of the Moon

The Earth also exerts tidal forces on the moon's rocky interior.

→ It is rotating with the same period around its axis as it is orbiting Earth (tidally locked).

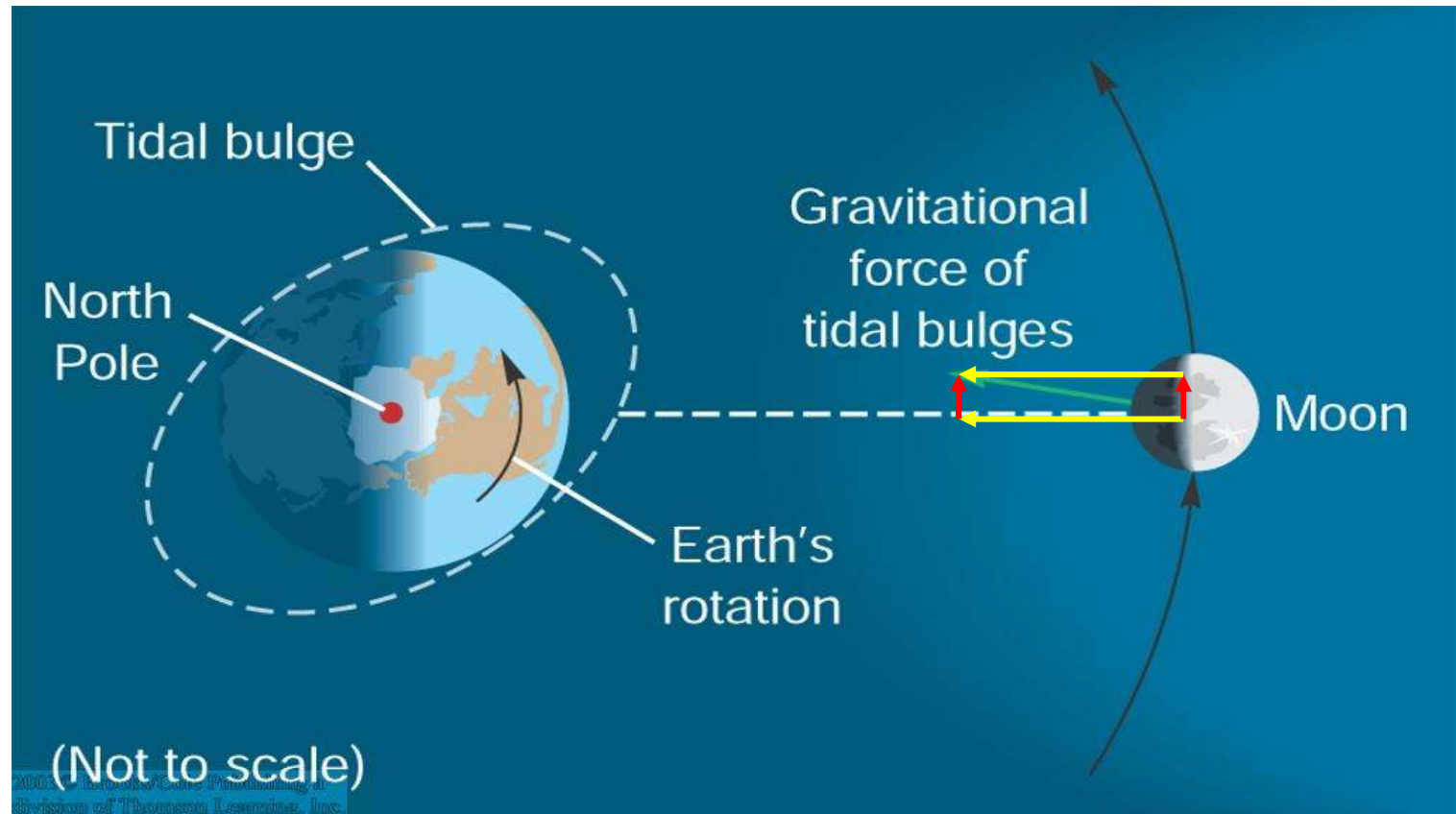
→ We always see the same side of the moon facing Earth.



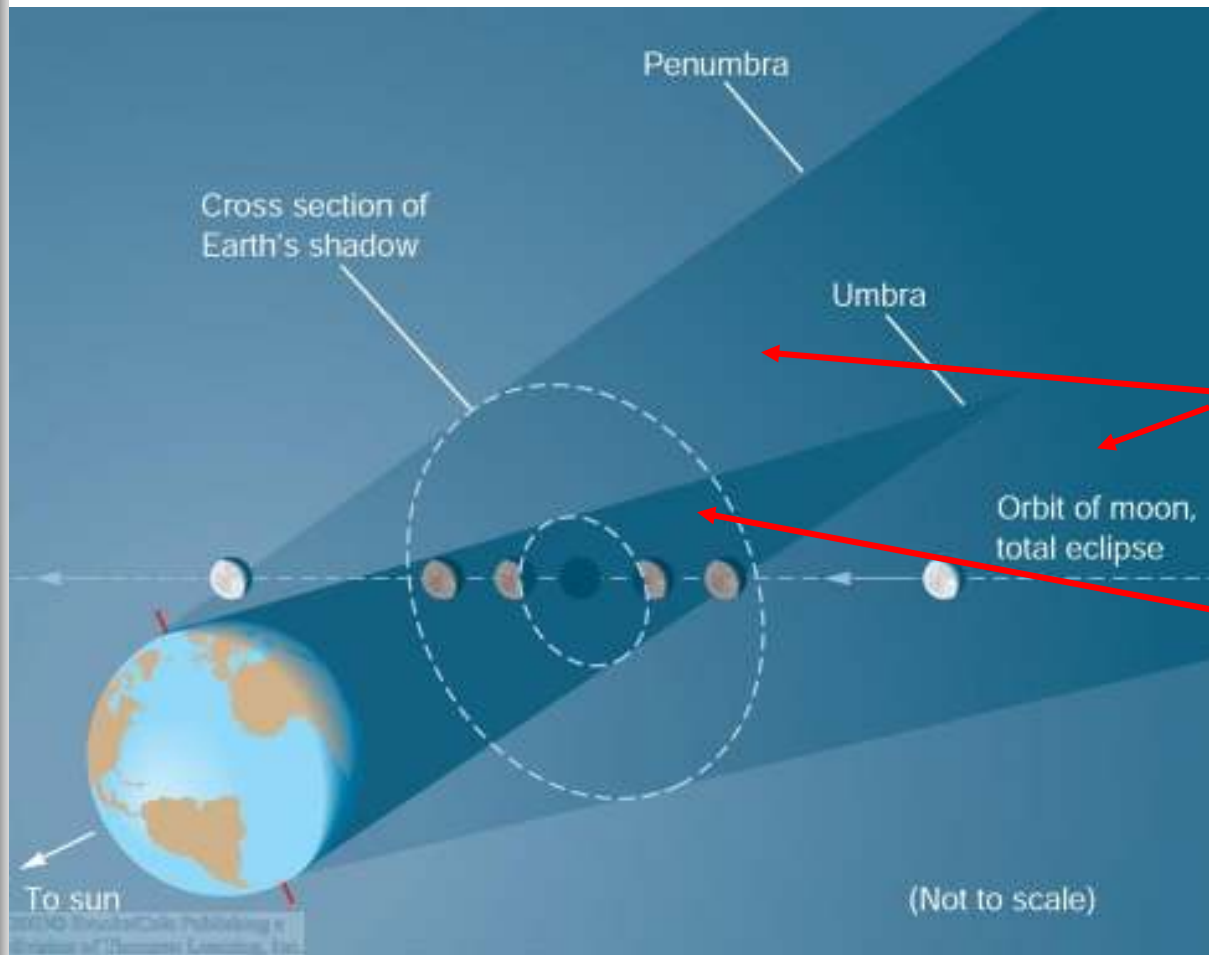
Acceleration of the Moon's Orbital Motion

Earth's tidal bulges are slightly tilted in the direction of Earth's rotation.

Gravitational force pulls the moon slightly forward along its orbit.



Lunar Eclipses

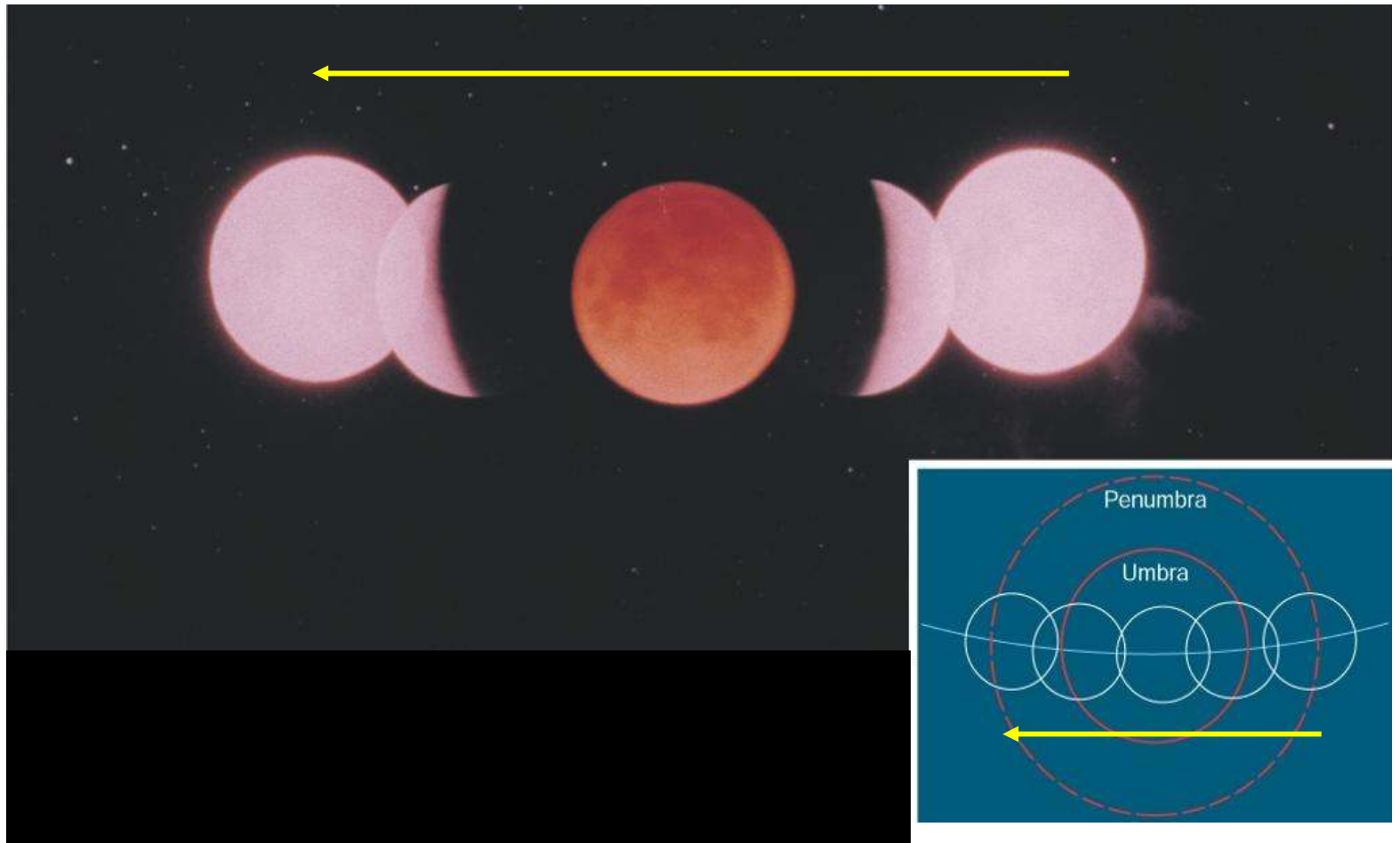


Earth's shadow consists of a zone of partial shadow, the **Penumbra**, and a zone of full shadow, the **Umbra**.

If the moon passes through Earth's full shadow (Umbra), we see a lunar eclipse.

If the entire surface of the moon enters the Umbra, the lunar eclipse is total.

A Total Lunar Eclipse (1)



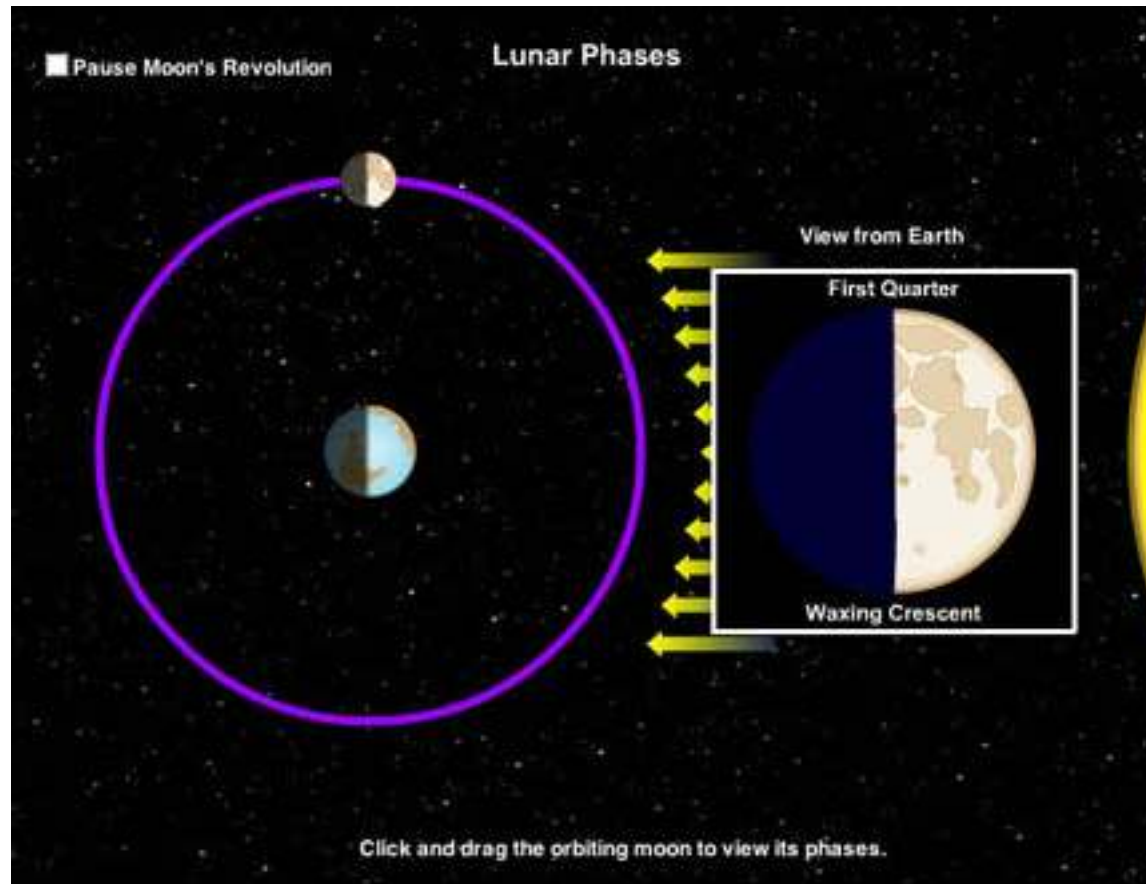
A Total Lunar Eclipse (2)



A total lunar eclipse can last up to 1 hour and 40 min.

During a total eclipse, the moon has a faint, red glow, reflecting sun light scattered in Earth's atmosphere.

Lunar Phases



PLAY
ANIMATION

(SLIDESHOW MODE ONLY)

Lunar Eclipses: 2002-2012

**Typically, 1 or
2 lunar
eclipses per
year.**

TABLE 3-1

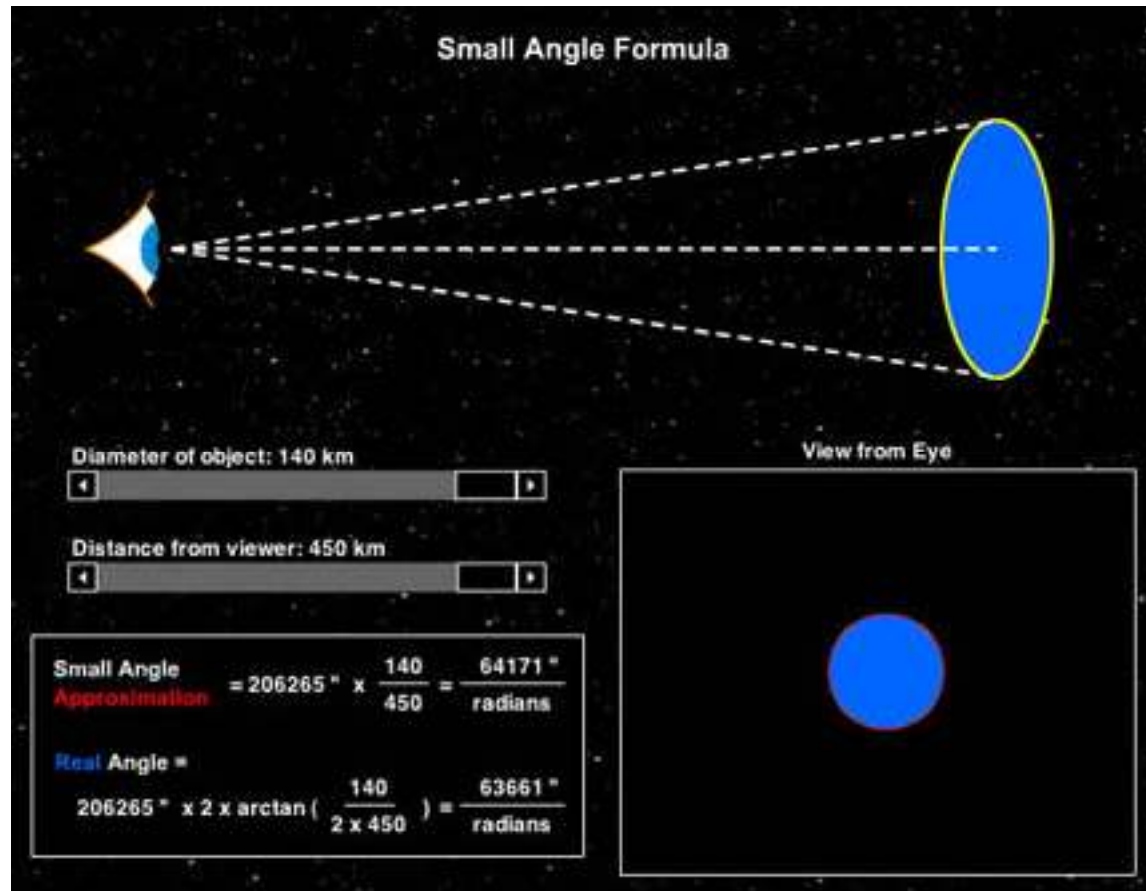
Total and Partial Eclipses of the Moon, 2004 to 2013

Year	Date	Time* of Midclipse (GMT)	Length of Totality (Hours:Min)	Length of Eclipse† (Hours:Min)
2004	May 4	20:32	1:16	3:22
2004	Oct. 28	3:05	1:20	3:38
2005	Oct. 17	12:04	Partial	0:56
2006	Sept. 7	18:52	Partial	1:30
2007	Mar. 3	23:22	1:14	3:40
2007	Aug. 28	10:38	1:30	3:32
2008	Feb. 21	3:27	0:50	3:24
2008	Aug. 16	21:11	Partial	3:08
2009	Dec. 31	19:24	Partial	1:00
2010	June 26	11:40	Partial	2:42
2010	Dec. 21	8:18	1:12	3:28
2011	June 15	20:13	1:40	3:38
2011	Dec. 10	14:33	0:50	3:32
2012	June 4	11:03	Partial	2:08
2013	April 25	20:10	Partial	0:28

*Times are Greenwich Mean Time. Subtract 5 hours for Eastern Standard Time, 6 hours for Central Standard Time, 7 hours for Mountain Standard Time, and 8 hours for Pacific Standard Time. From your time zone, lunar eclipses that occur between sunset and sunrise will be visible, and those at midnight will be best placed.

†Does not include penumbral phase.

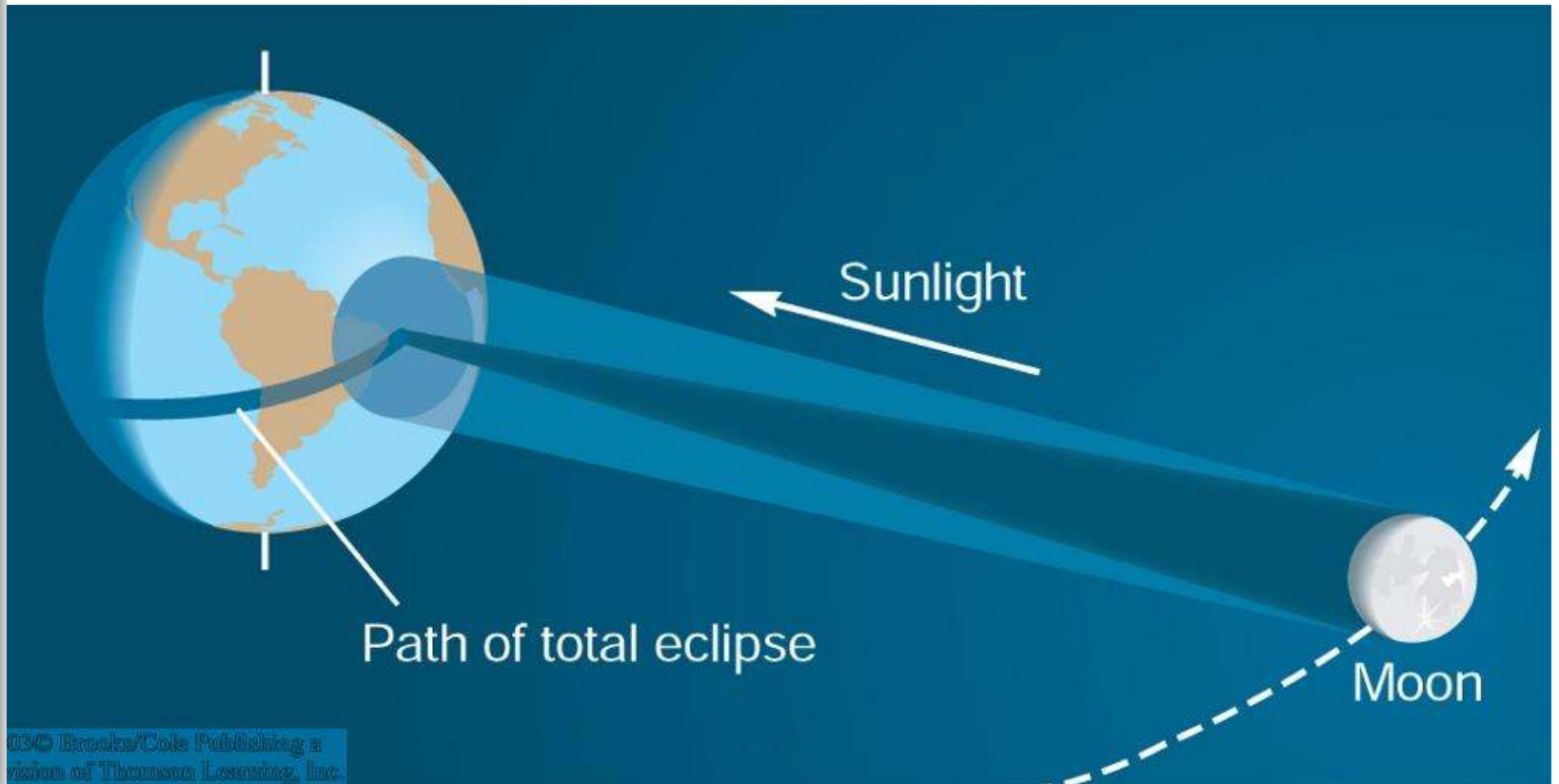
Small Angle Formula



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ANIMATION

(SLIDESHOW MODE ONLY)

Solar Eclipses



The sun appears approx. as large in the sky (same angular diameter $\sim 0.5^\circ$) as the moon.

→ When the moon passes in front of the sun, the moon can cover the sun completely, causing a total solar eclipse.

Solar Eclipses: 2002-2012

Approximately 1 total solar eclipse per year

TABLE 3-2

Total and Annular Eclipses of the Sun, 2004** to 2014

Date	Total/Annular (T/A)	Time of Mideclipse* (GMT)	Maximum Length of Total or Annular Phase (Min:Sec)	Area of Visibility
2005 Apr. 8	AT	21 ^h	0:42	Pacific, N. of S. America
2005 Oct. 3	A	11 ^h	4:32	Atlantic, Spain, Africa
2006 Mar. 29	T	10 ^h	4:07	Atlantic, Africa, Turkey
2006 Sept. 22	A	12 ^h	7:09	N.E. of S. America, Atlantic
2008 Feb. 7	A	4 ^h	2:14	S. Pacific, Antarctica
2008 Aug. 1	T	10 ^h	2:28	Canada, Arctic, Siberia
2009 Jan. 26	A	8 ^h	7:56	S. Atlantic, Indian Ocean
2009 July 22	T	3 ^h	6:40	Asia, Pacific
2010 Jan. 15	A	7 ^h	11:10	Africa, Indian Ocean
2010 July 11	T	20 ^h	5:20	Pacific, S. America
2012 May 20	A	23 ^h	5:46	Japan, N. Pacific, W. US
2012 Nov. 13	T	22 ^h	4:02	N. Australia, S. Pacific
2013 May 10	A	0 ^h	6:04	Australia, Pacific
2013 Nov. 3	AT	13 ^h	1:40	Atlantic, Africa

The next major total solar eclipse visible from the United States will occur on August 21, 2017.

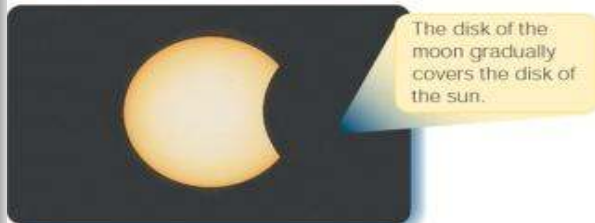
*Times are Greenwich Mean Time. Subtract 5 hours for Eastern Standard Time, 6 hours for Central Standard Time, 7 hours for Mountain Standard Time, and 8 hours for Pacific Standard Time.

^hhours.

**There are no total or annular eclipses of the sun during 2004 or 2014.

Total Solar Eclipse

A Total Solar Eclipse



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Chromosphere and Corona

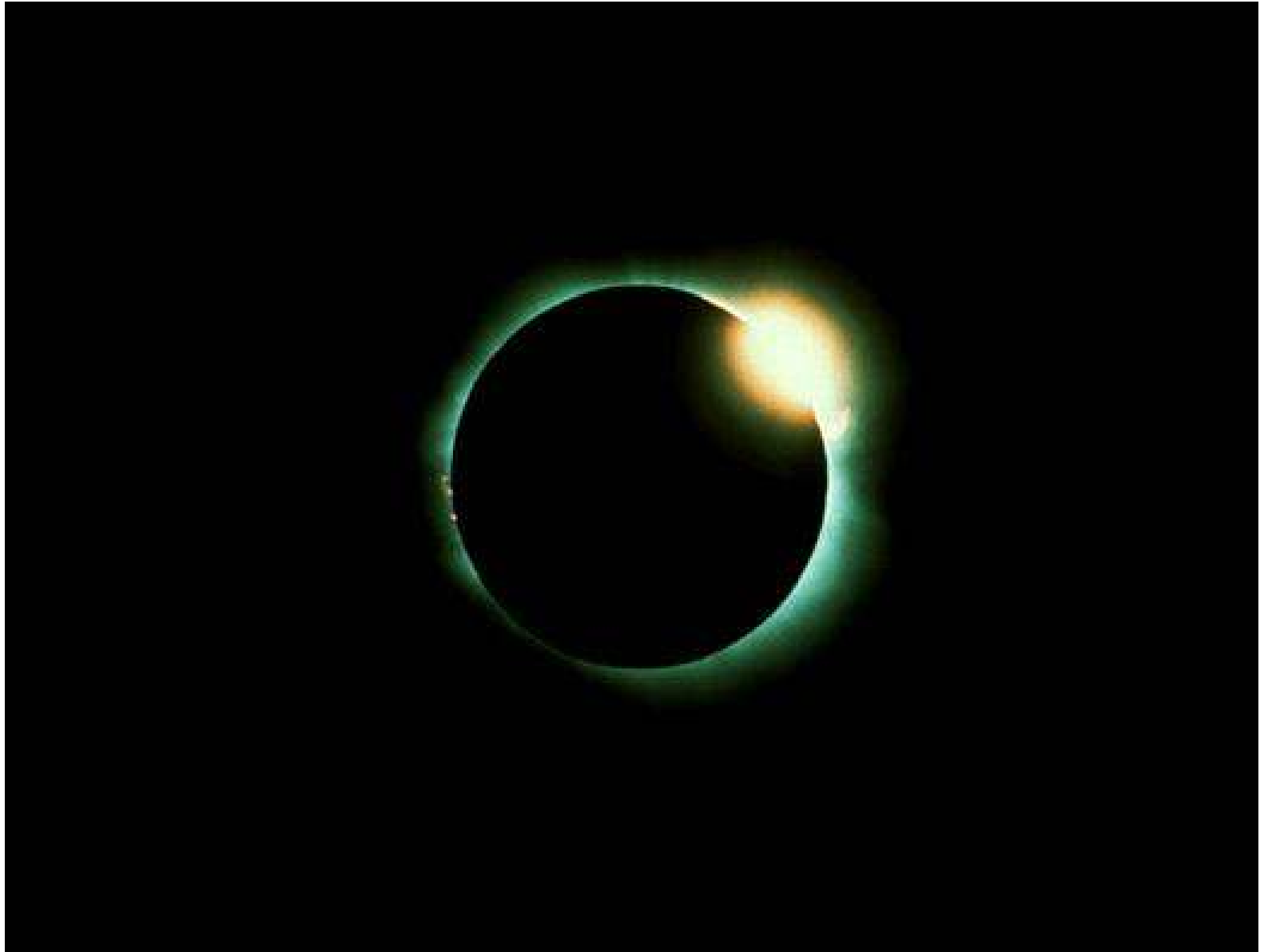
Prominences

2003© Brooks/Cole Publishing a
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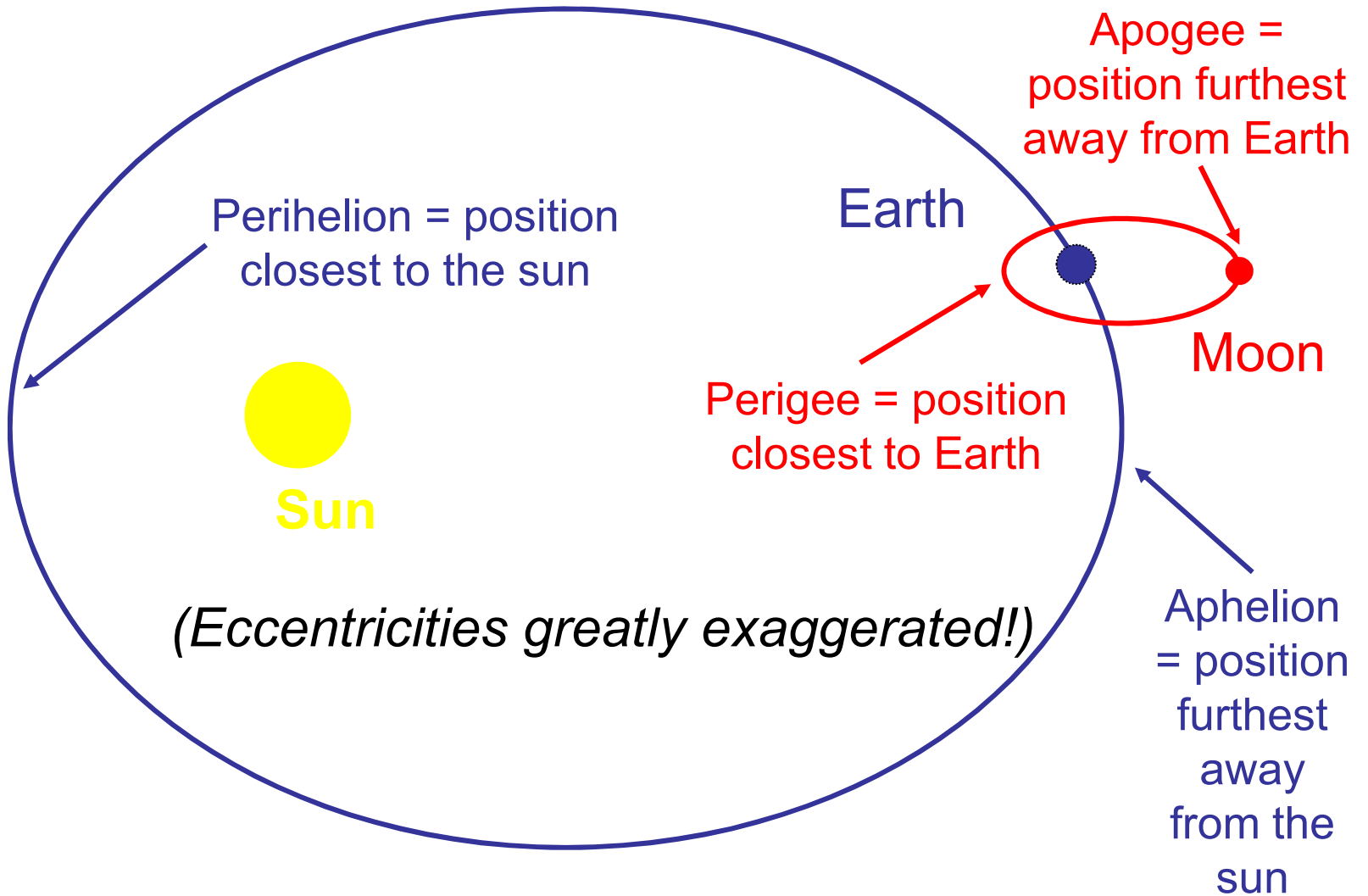
Solar Atmosphere Revealed



Diamond Ring Effect

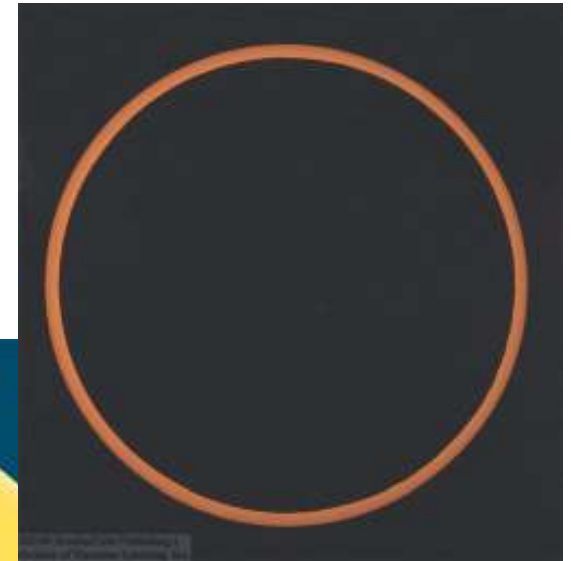
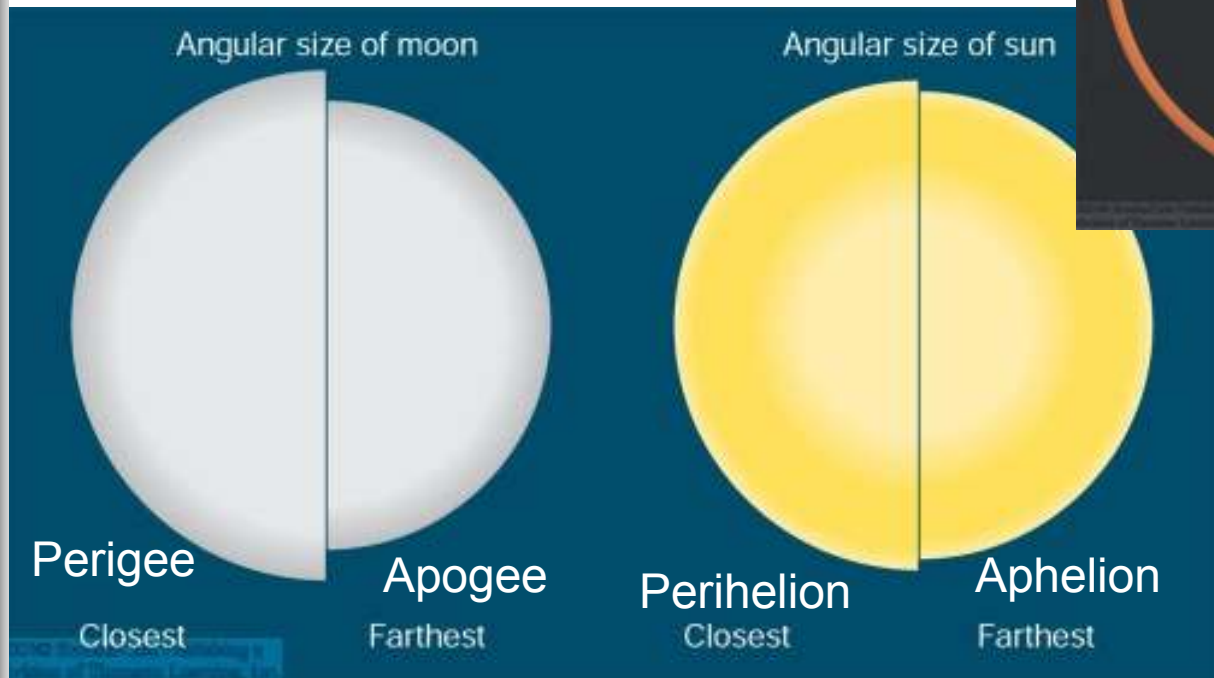


Earth and Moon's Orbits Are Slightly Elliptical



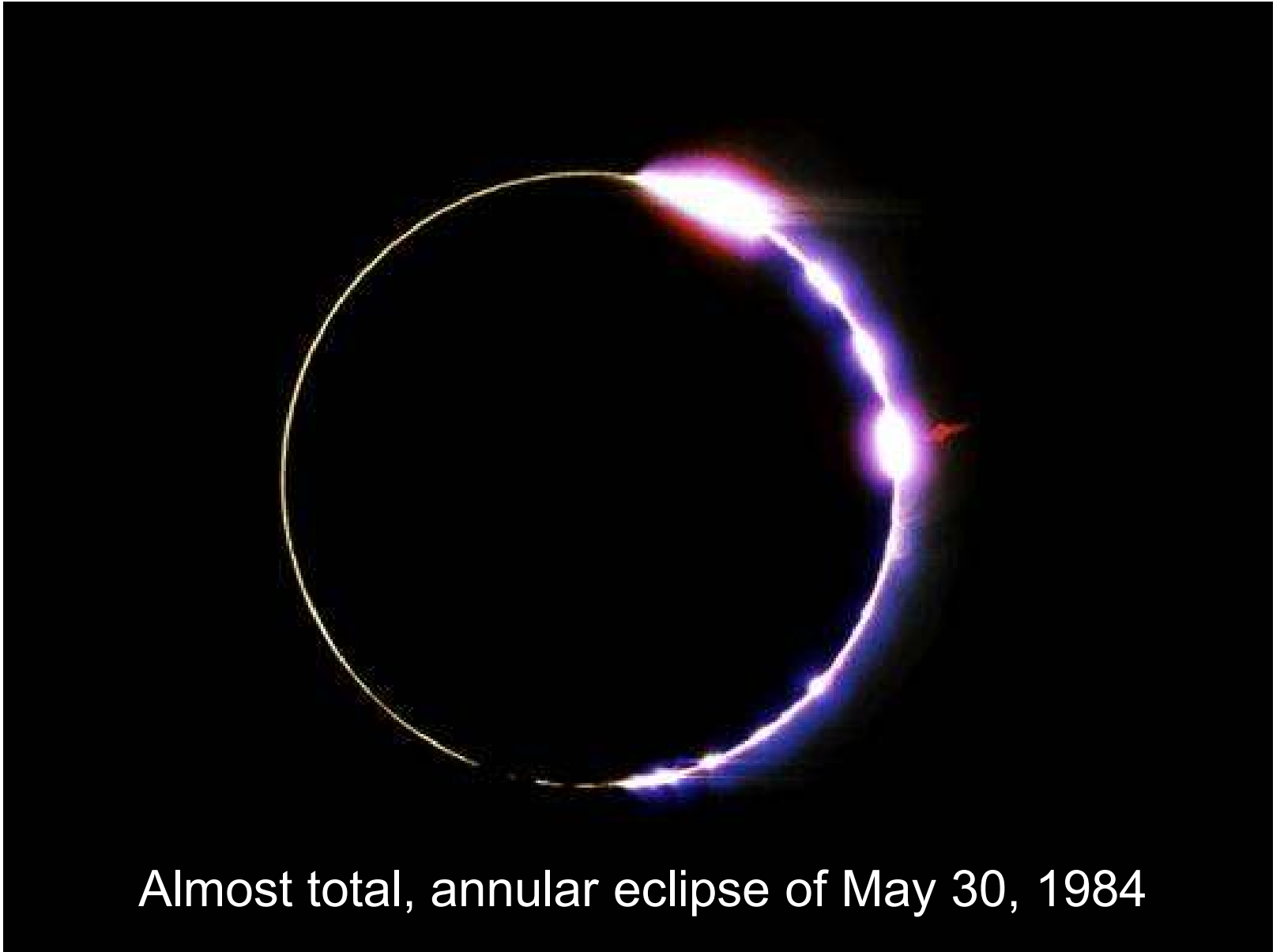
Annular Solar Eclipses

When Earth is near perihelion, and the moon is near apogee, we see an annular solar eclipse.



The angular sizes of the moon and the sun vary, depending on their distance from Earth.

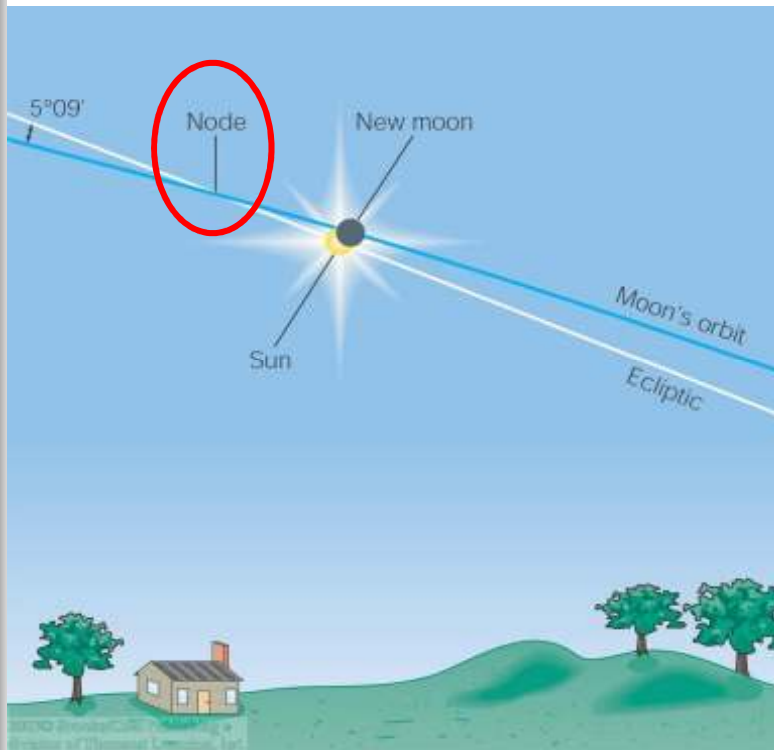
Annular Solar Eclipses (2)



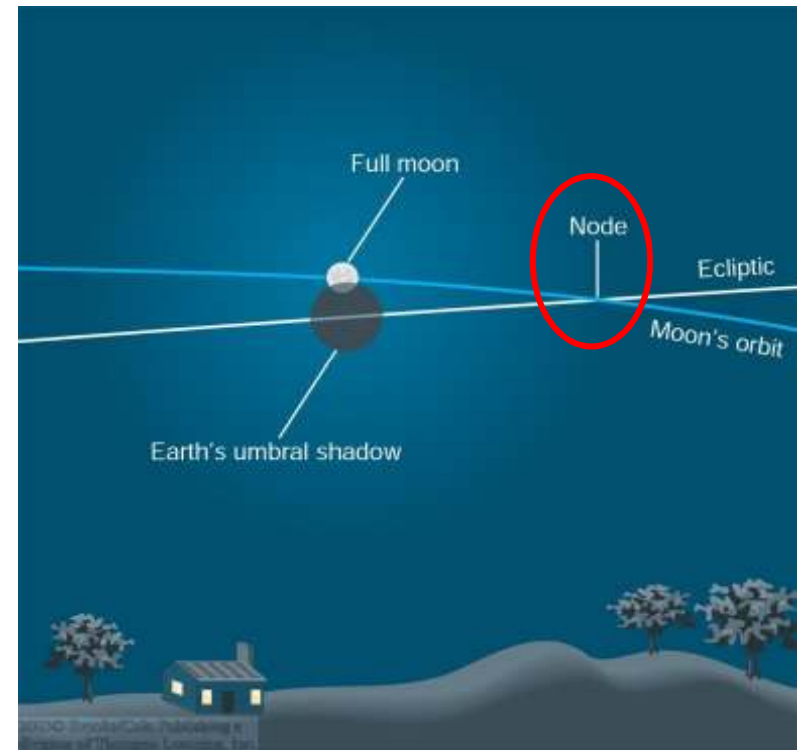
Almost total, annular eclipse of May 30, 1984

Conditions for Eclipses (1)

The moon's orbit is inclined against the ecliptic by $\sim 5^\circ$.



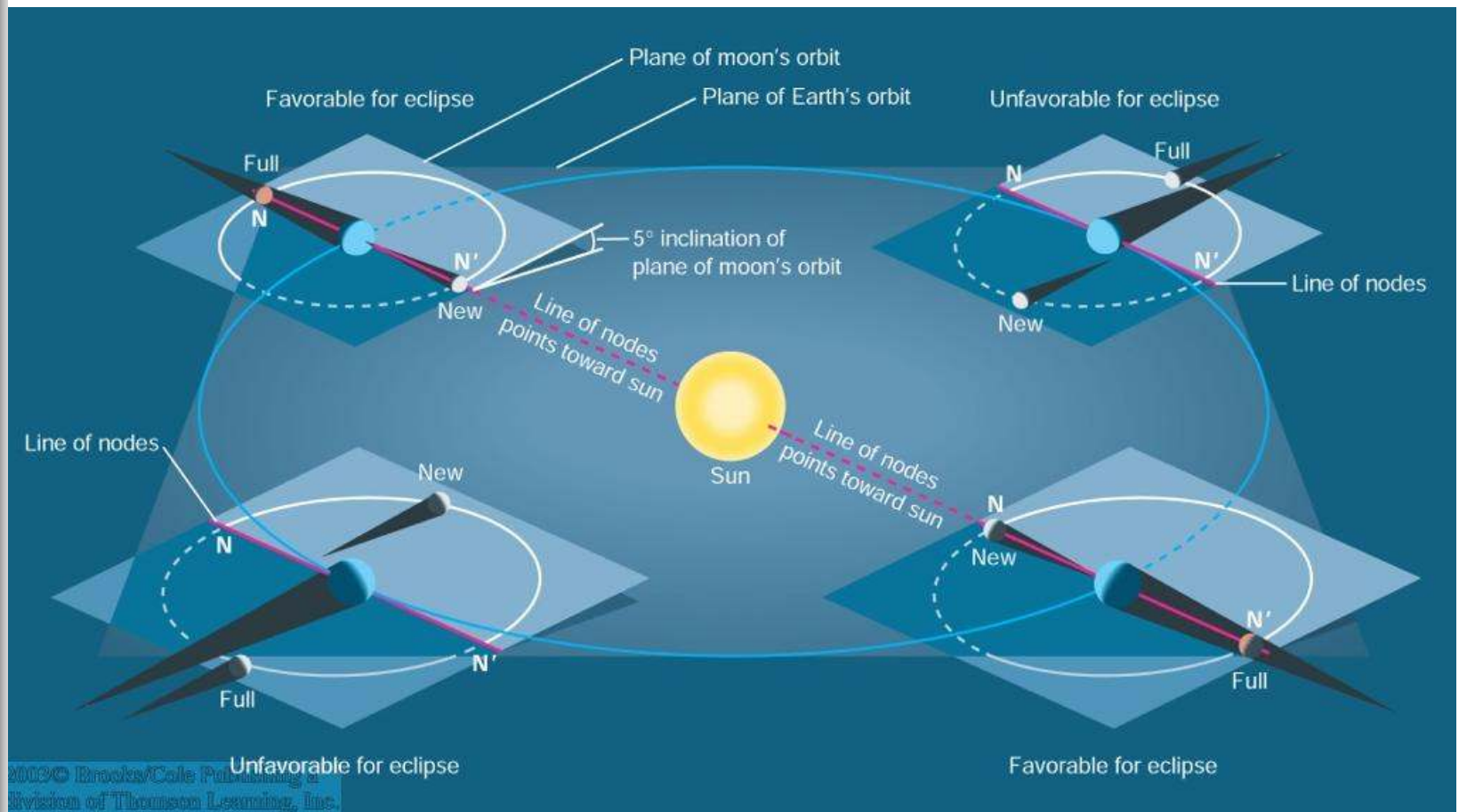
A solar eclipse can only occur if the moon passes a node near new moon.



A lunar eclipse can only occur if the moon passes a node near full moon.

Conditions for Eclipses (2)

Eclipses occur in a cyclic pattern.



STOP

→ **Saros cycle:** 18 years, 11 days, 8 hours