Ch. 1 *Charting the Heavens*

The Moon and Eclipses

1.5 Motion of the Moon

The Moon is a natural satellite of the Earth.

It is about 2160 miles in Diameter and about 239,000 miles away from the Earth, on average. → 110 x its diam away

Its distance changes because the orbit is elliptical. (e=.055)

The Moon's orbital plane is tilted by 5.15 degrees with respect to the ecliptic plane.
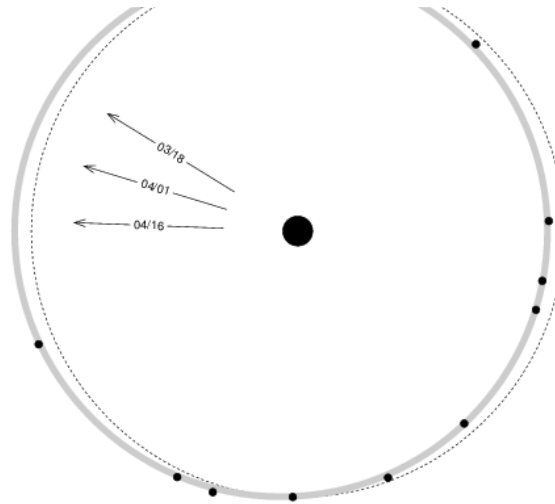
The Moon and Earth interact tidally.

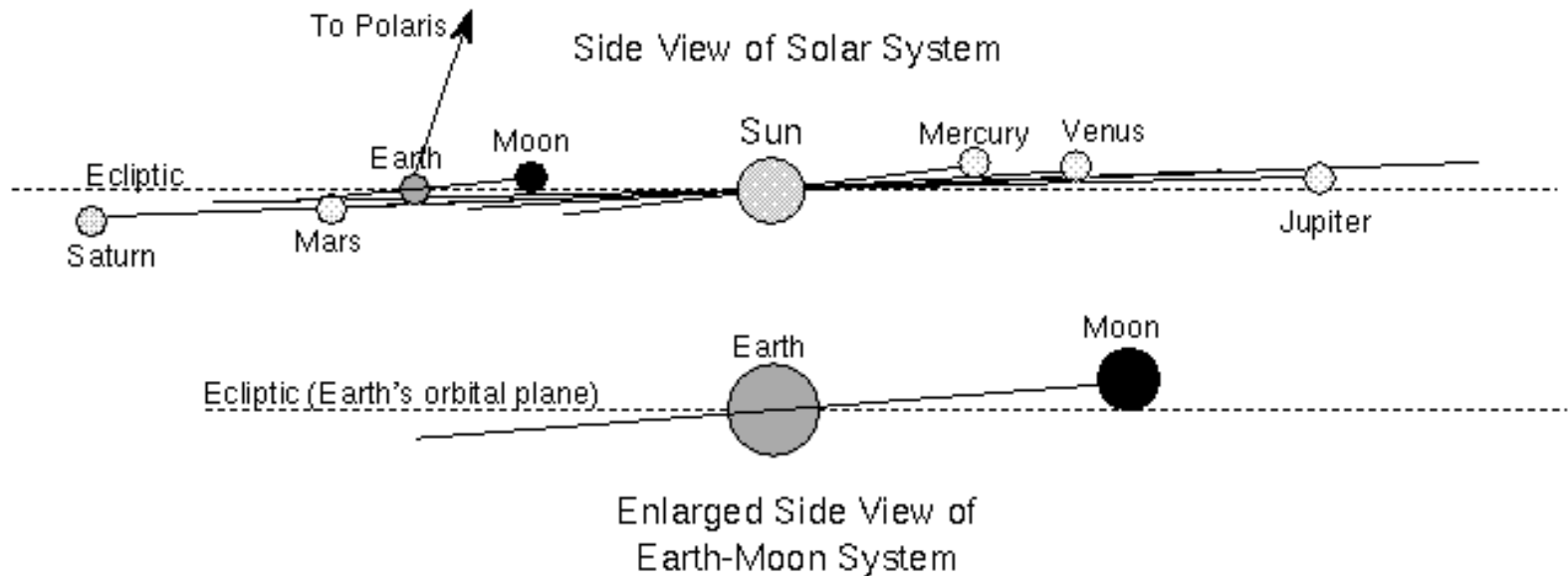→ **The Moon – Earth system is a complex one!**

We have no less than 5 different months all based on the time it takes for the Moon to go around the Earth.

Tilt of the Moon's orbit

Top View:

03/18
04/01
04/16

Side View:

To Polaris

Side View of Solar System

Ecliptic
Earth
Moon
Sun
Mercury
Venus
Saturn
Mars
Jupiter

Ecliptic (Earth's orbital plane)
Earth
Moon

Enlarged Side View of
Earth-Moon System

1.5 Motion of the Moon

1) Sidereal Month:
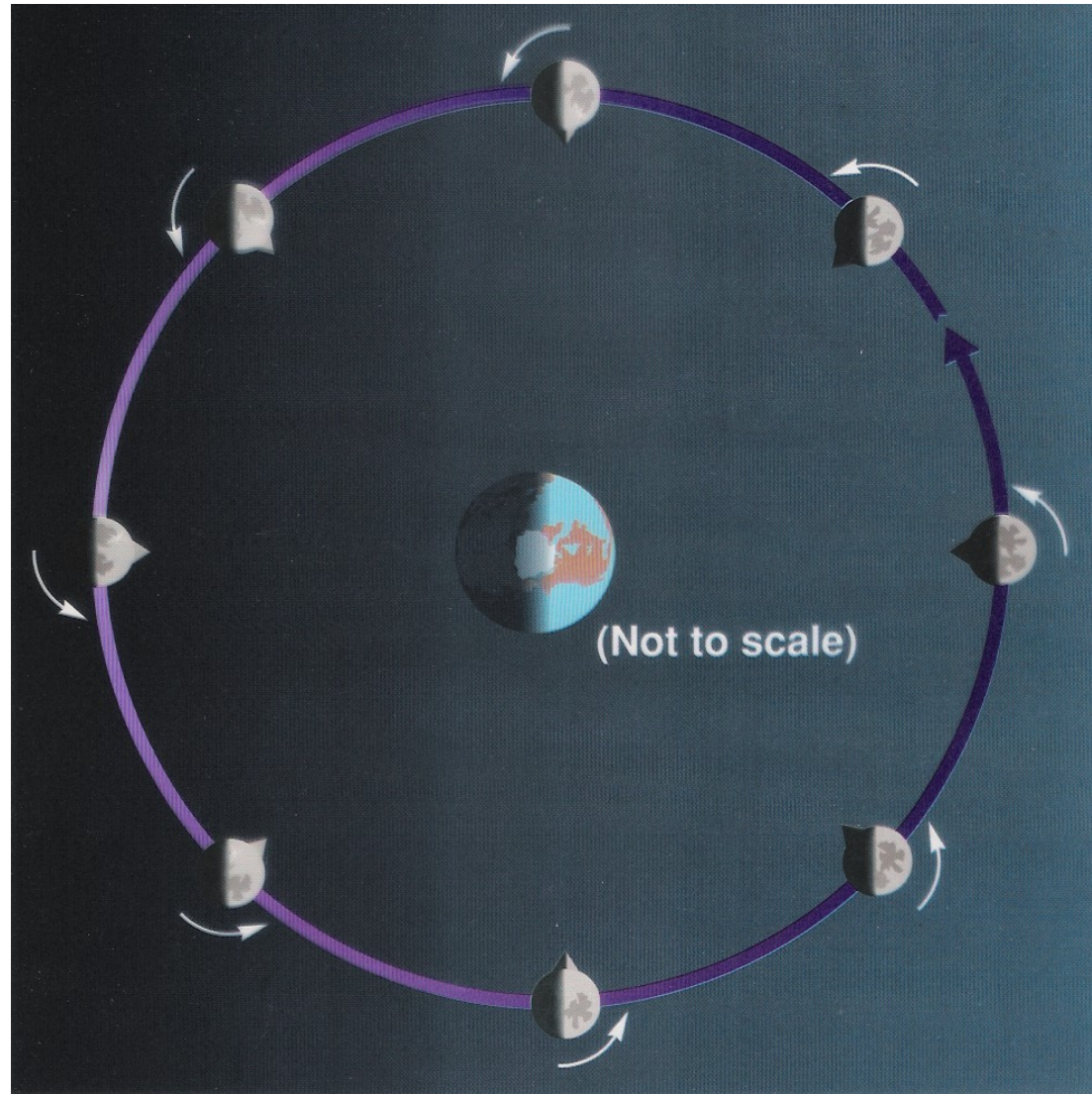time to orbit relative
to stars = **27.3 days.**

2) Synodic Month:
time to orbit relative
to Sun = **29.5 days.**
Same as the "phase
month".

**Why is the synodic
month longer?**

**How fast does Moon
move relative to
stars?**
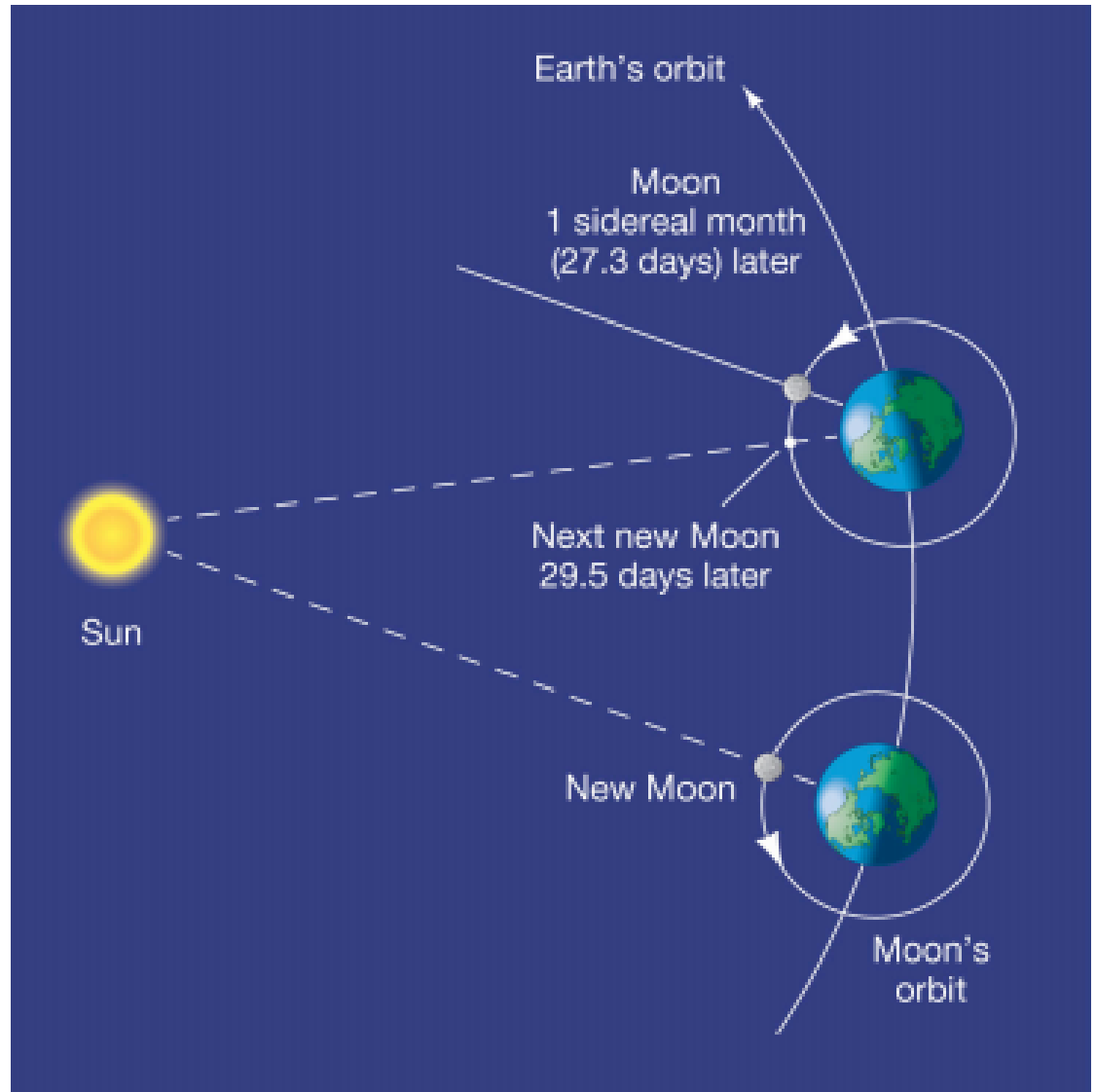
Q: Does the Moon rotate? (Relative to stars, Earth?)
Q: Is there a "dark side" of the Moon, or a "far side"?

(Not to scale)

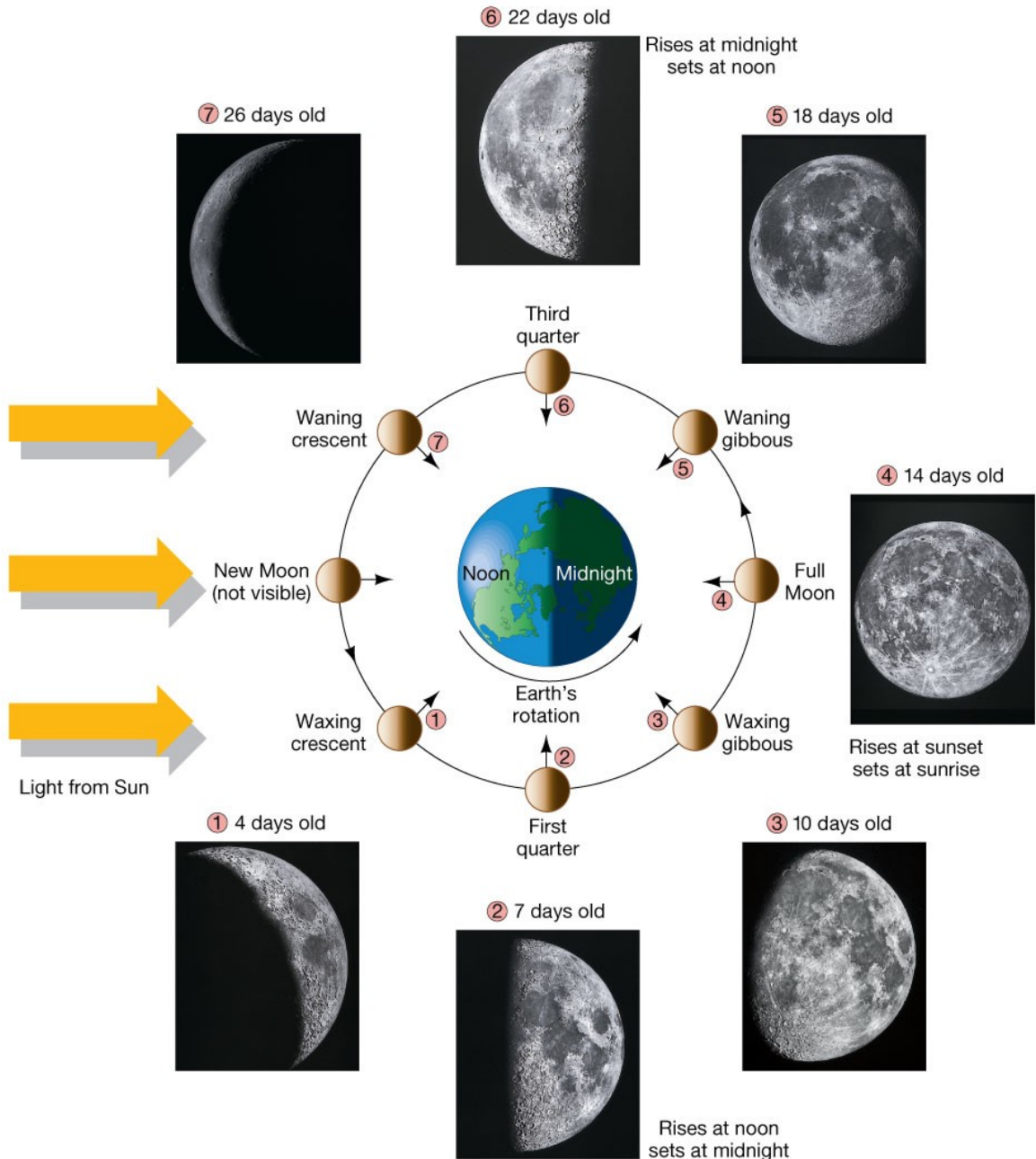**See Moon globe, and YouTube videos about *libration*.**

1.5 Motion of the Moon

Phases are due to different amounts of sunlit portion being visible from Earth.
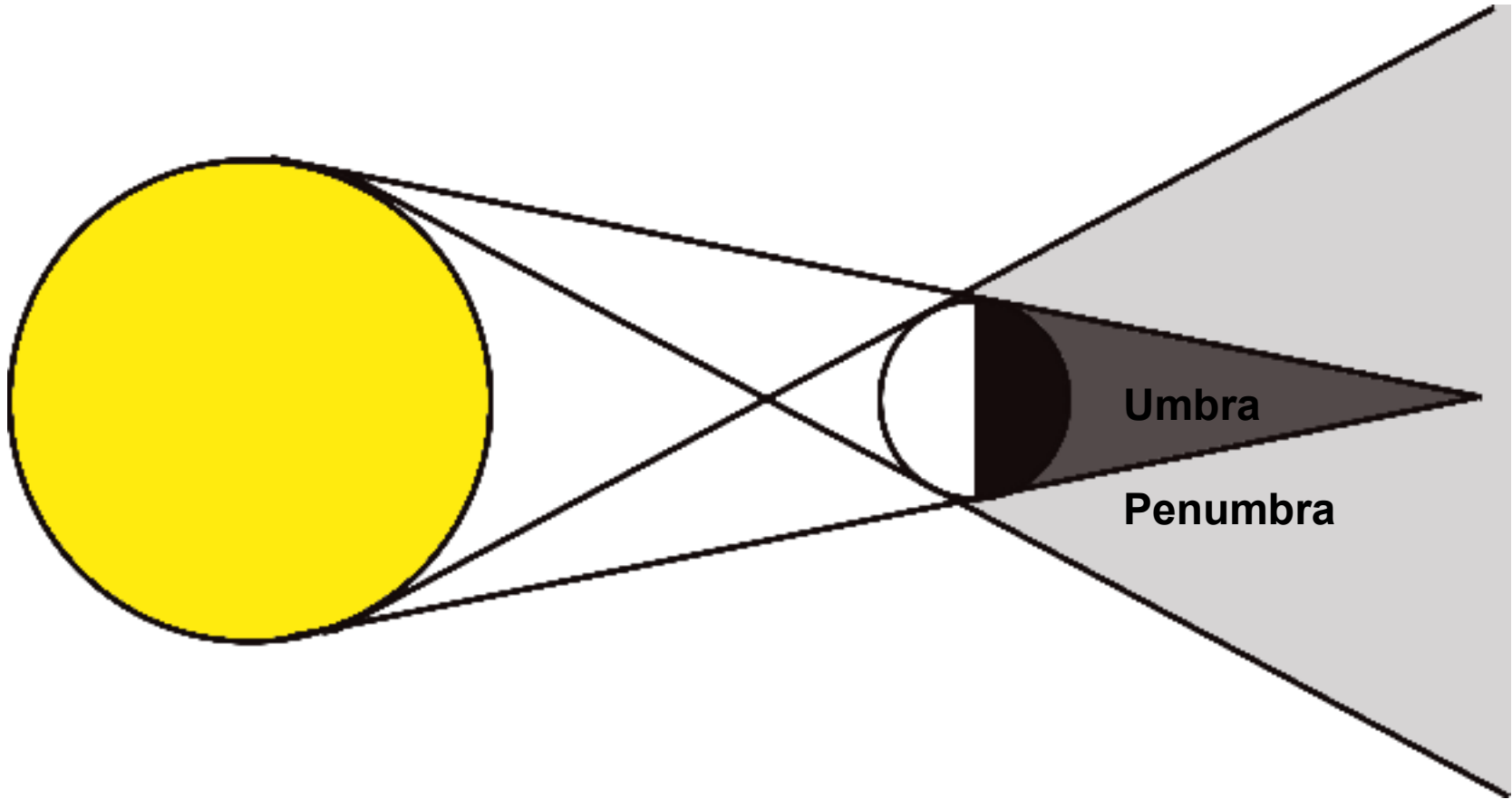
Q: Seen from Earth, what angle (ccw) is between the Sun and the Full Moon?

Q: Place a stick figure on Earth representing an observer experiencing morning.

Q: What time would a 1st quarter Moon rise?

⑥ 22 days old
Rises at midnight
sets at noon

⑦ 26 days old

⑤ 18 days old

Third quarter

Waning crescent ⑦

Waning gibbous ⑤

④ 14 days old

New Moon (not visible)

Noon   Midnight

Full Moon ④

Earth's rotation

Waxing crescent ①

Waxing gibbous ③

Light from Sun

First quarter

Rises at sunset sets at sunrise

① 4 days old

② 7 days old

③ 10 days old

Rises at noon sets at midnight

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Eclipse Basics – the shadow cone geometry.

Eclipse Basics.

**Solar Eclipses – the shadow of the Moon falls on the Earth.
We (on Earth) see the Sun get obscured.**

> **TYPES: Partial
>   Annular
>   Hybrid or mixed** (e.g. start annular, end total)
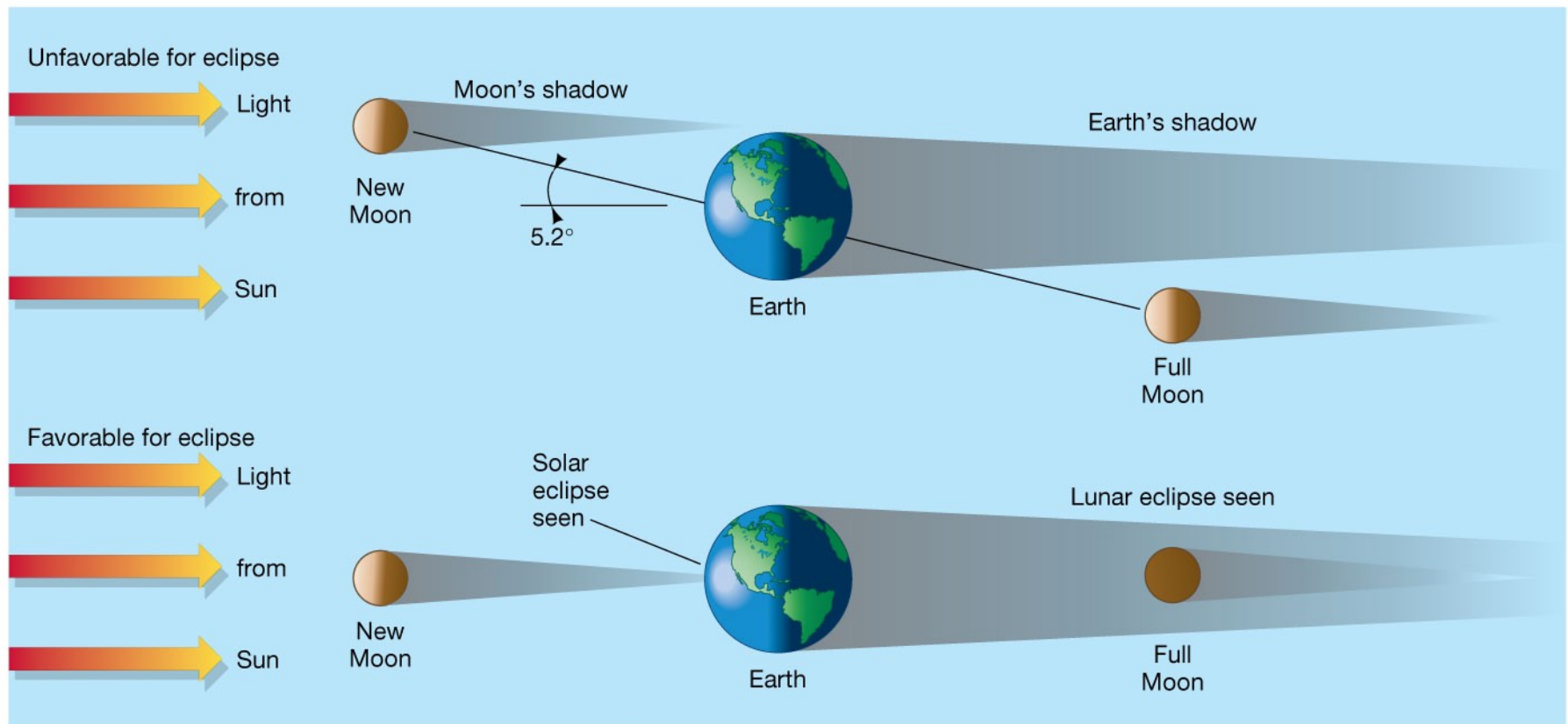> **   Total**

**Lunar Eclipses – the shadow of the Earth falls on the Moon.
We see a shadow pass over the Moon.**

> **TYPES: Penumbral
>   Partial
>   Total**

**Q: What phase does the Moon have to be in, if any, during a solar
eclipse? During a lunar eclipse?**

1.5 Motion of the Moon – *Eclipses!*

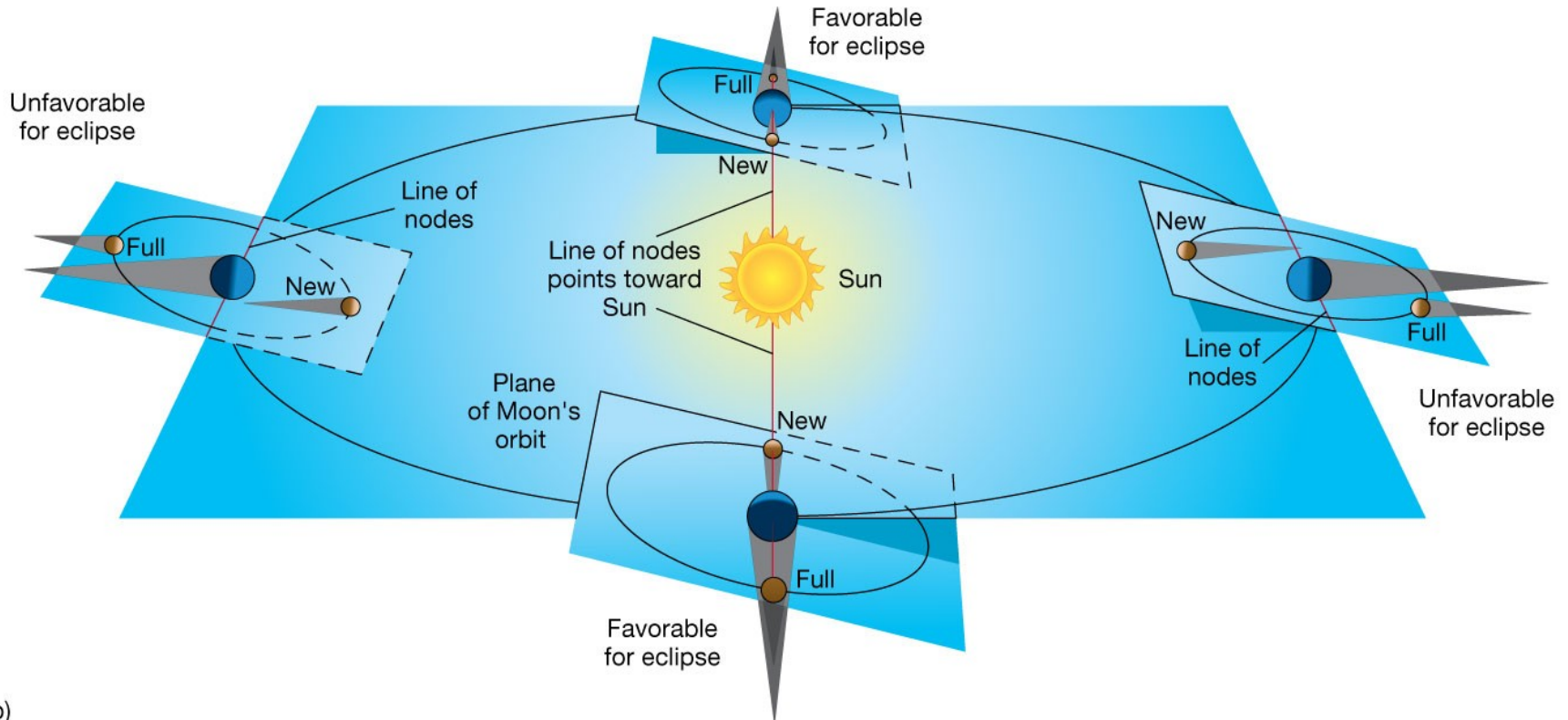**Eclipses** occur when Earth, Moon, and Sun form a straight line (*syzygy*).

1.5 Motion of the Moon

Eclipses don't occur every month because Earth's and Moon's orbits are not in the same plane

(b)
© 2011 Pearson Education, Inc.
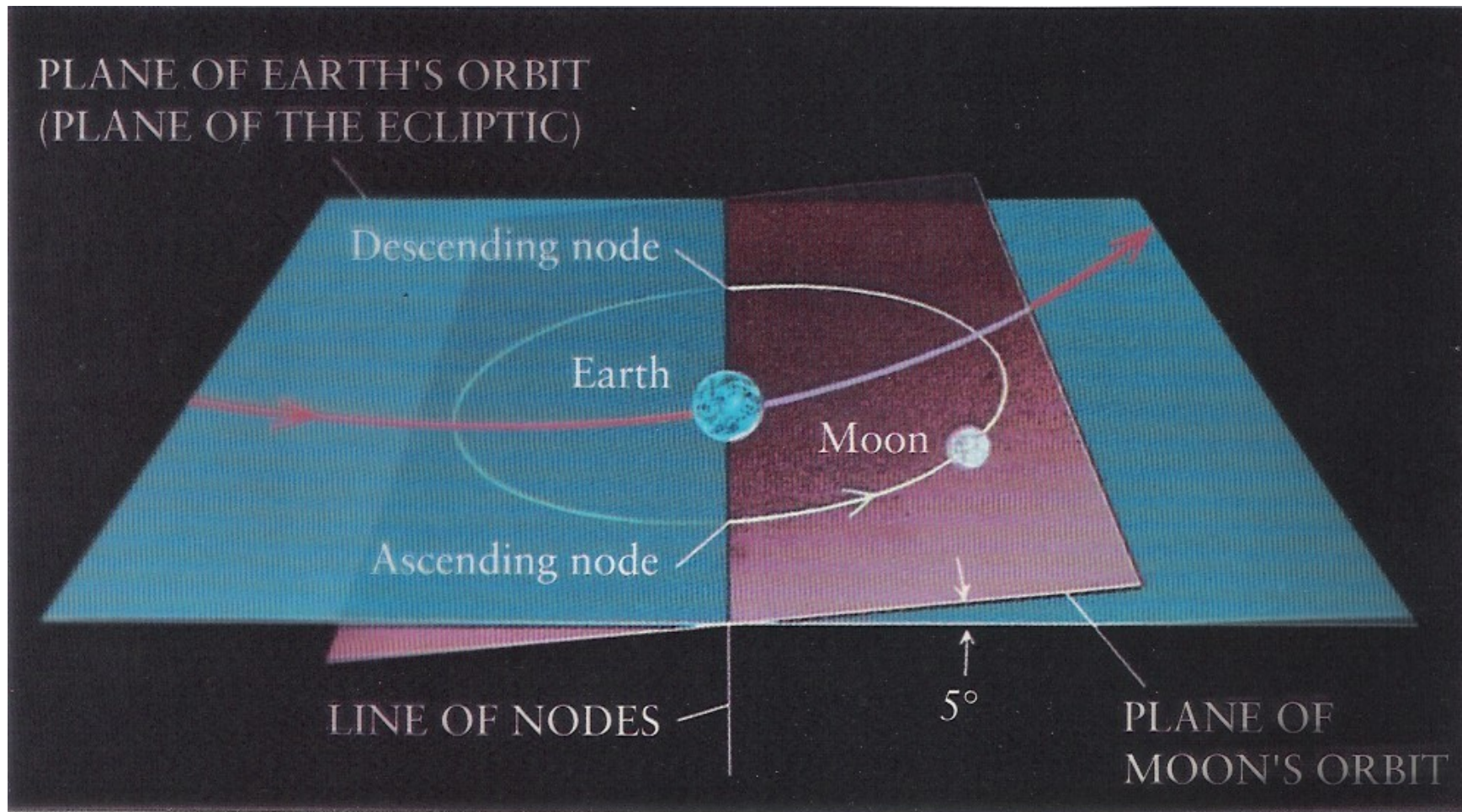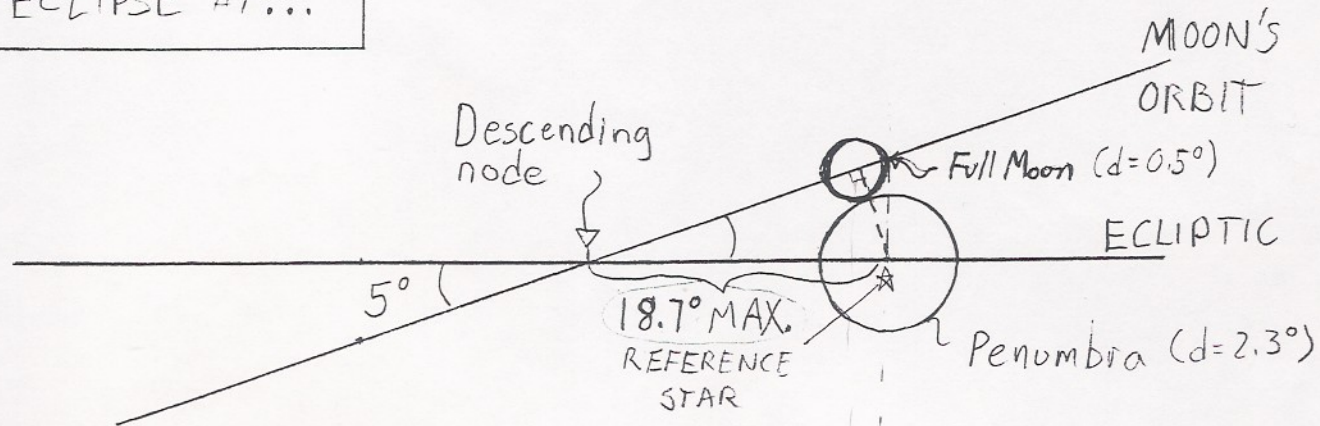
1.5 Motion of the Moon

Moon's orbit intersects ecliptic plane at a *line of nodes*.

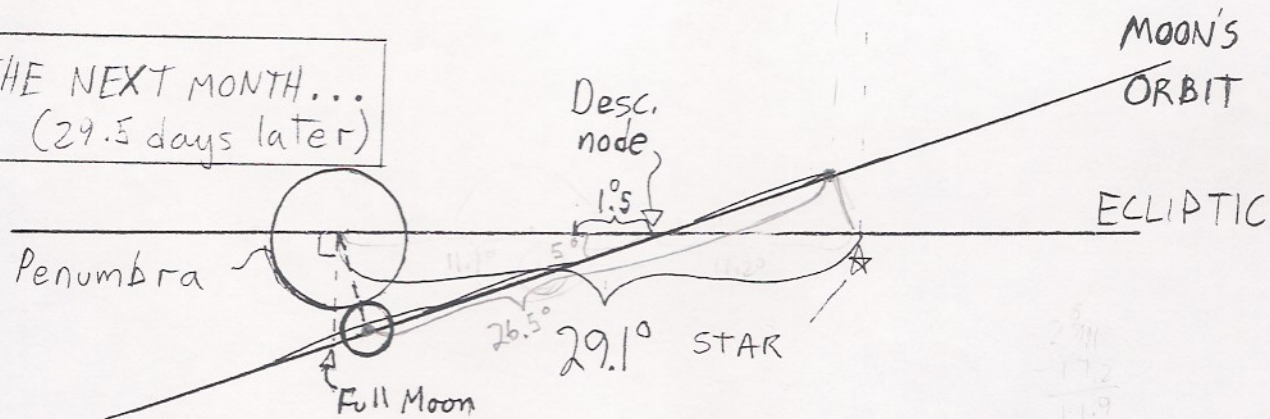**The line of nodes connects two points: an ascending node and a descending node.**
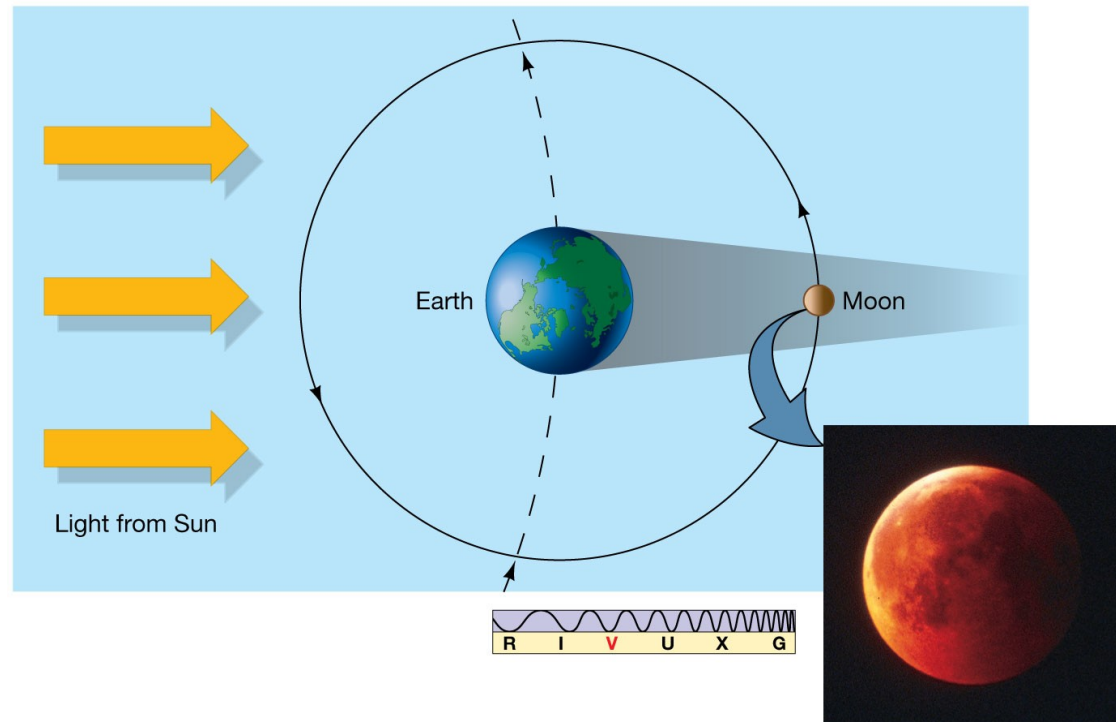
ECLIPSE #1...

MOON'S ORBIT

Descending node

Full Moon (d=0.5°)

ECLIPTIC

5°

18.7° MAX.
REFERENCE STAR

Penumbra (d=2.3°)

THE NEXT MONTH...
(29.5 days later)

MOON'S ORBIT

Desc. node

1.5

ECLIPTIC

Penumbra

5°

26.5°   29.1°   STAR

Full Moon

TWO PENUMBRAL'S IN ONE MONTH!
Degrees and diameters are
(Not to scale.)

Lunar eclipses – Earth is between Moon and Sun

- **Types determined by maximum immersion**

- *Partial* **if Moon only partially enters Umbra**

- *Total* **if Moon completely enters Umbra**

- *Penumbral* **when Moon only enters penumbra**

Earth

Moon

Light from Sun
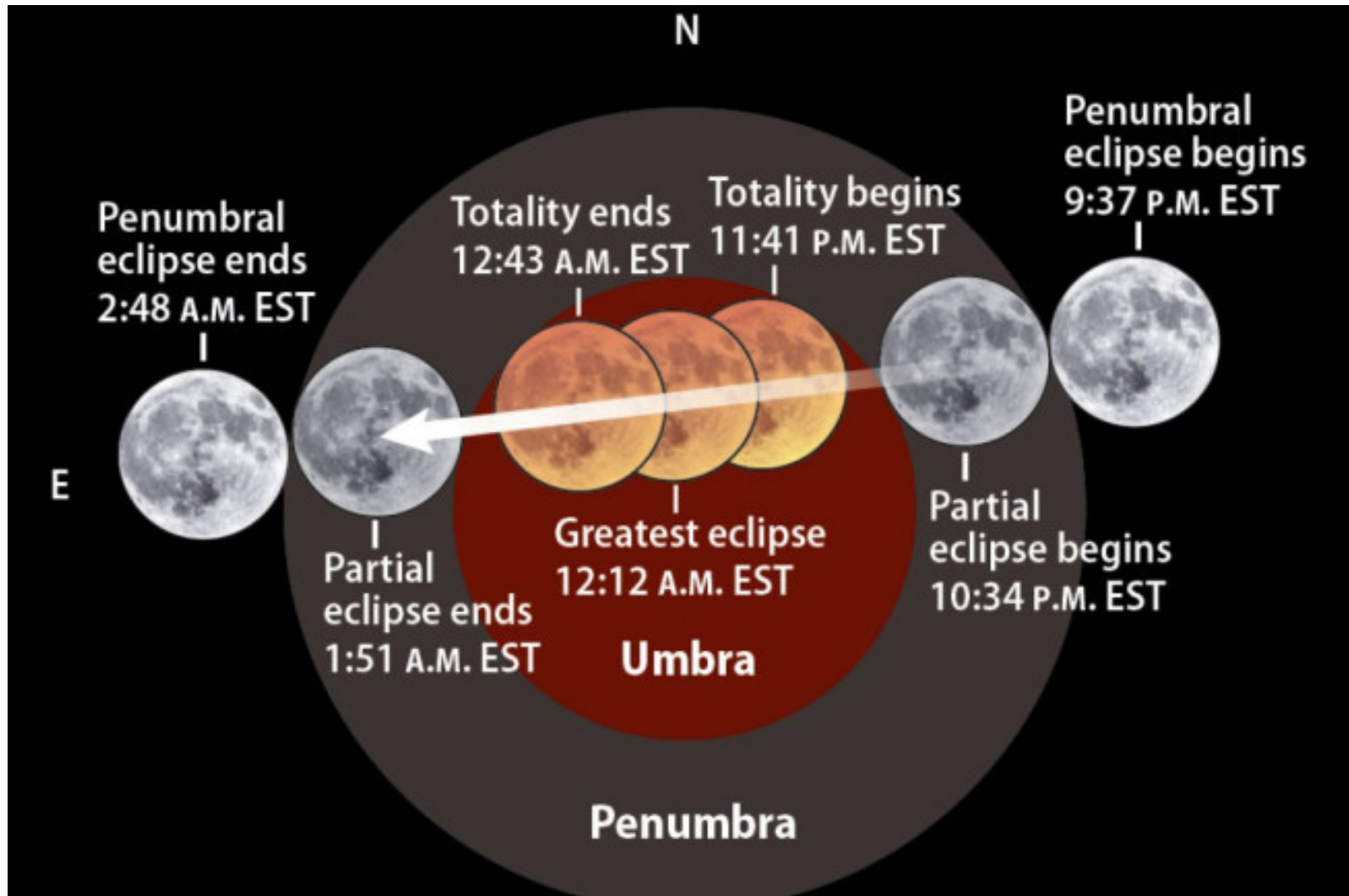
R I V U X G

Lunar eclipses – Earth is between Moon and Sun
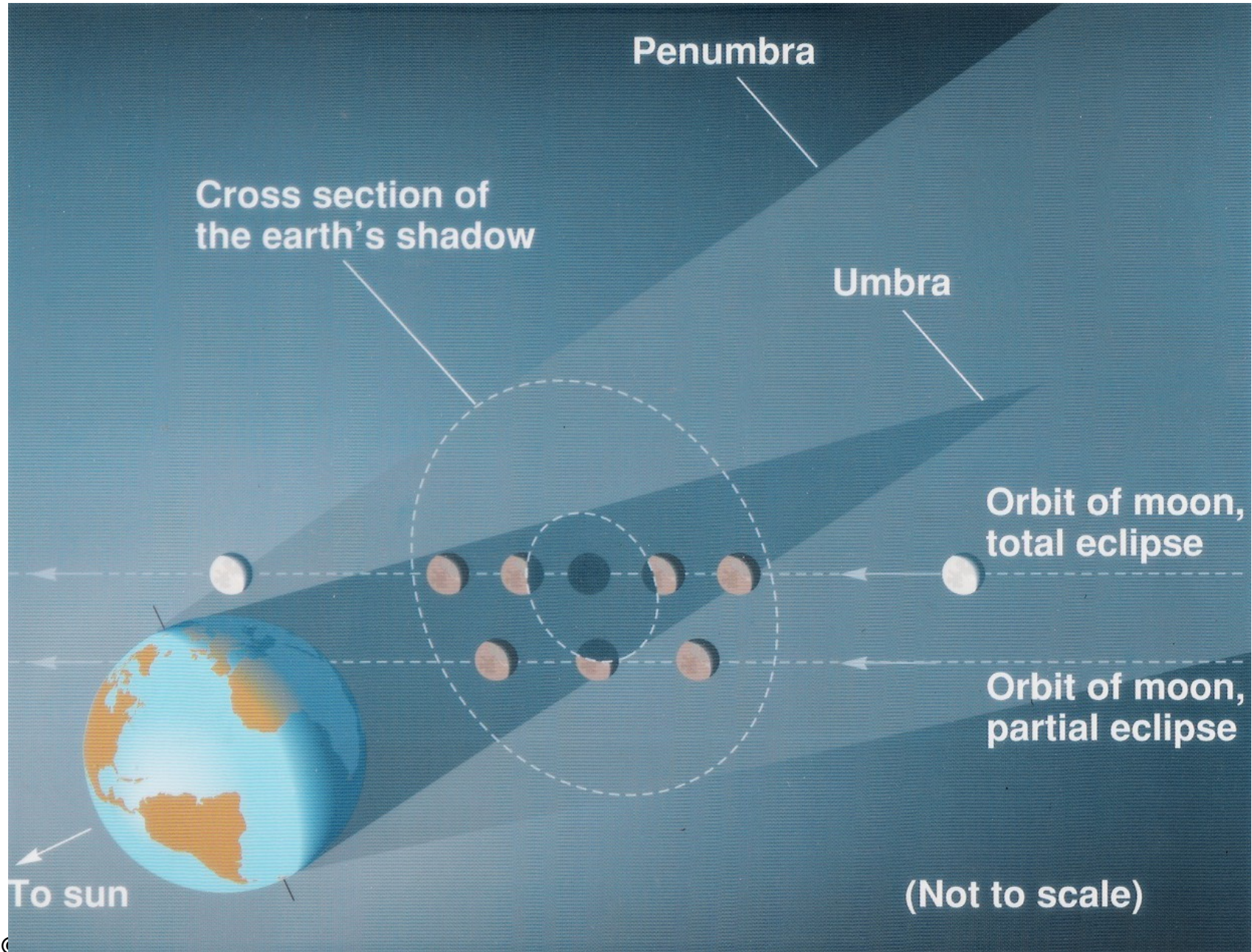
Lunar Eclipses!
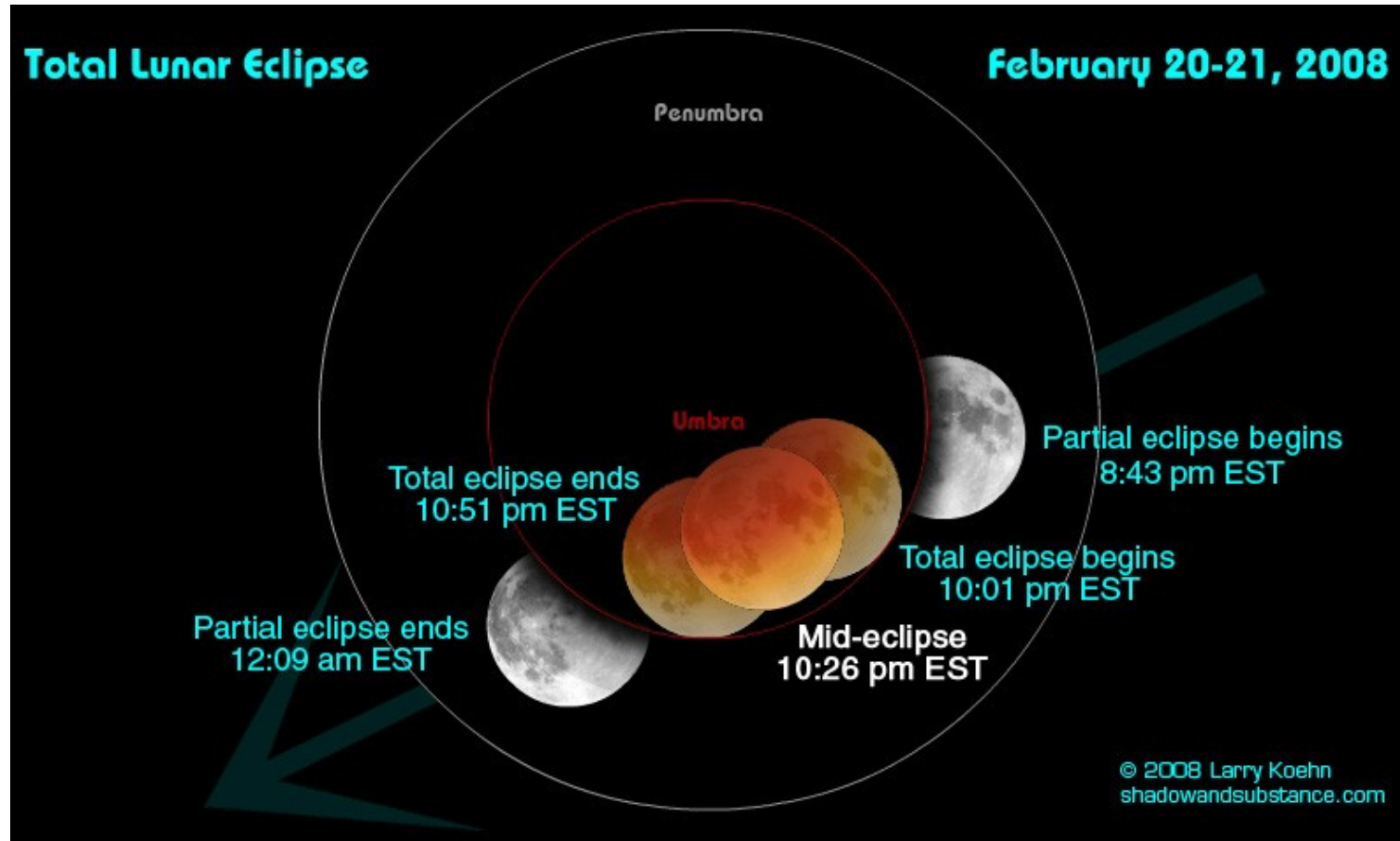
Total Lunar Eclipse, 1/20-21/2019

Lunar Eclipses!

My Pics from Jan 20-21, 2019 TLE

Lunar Eclipses!

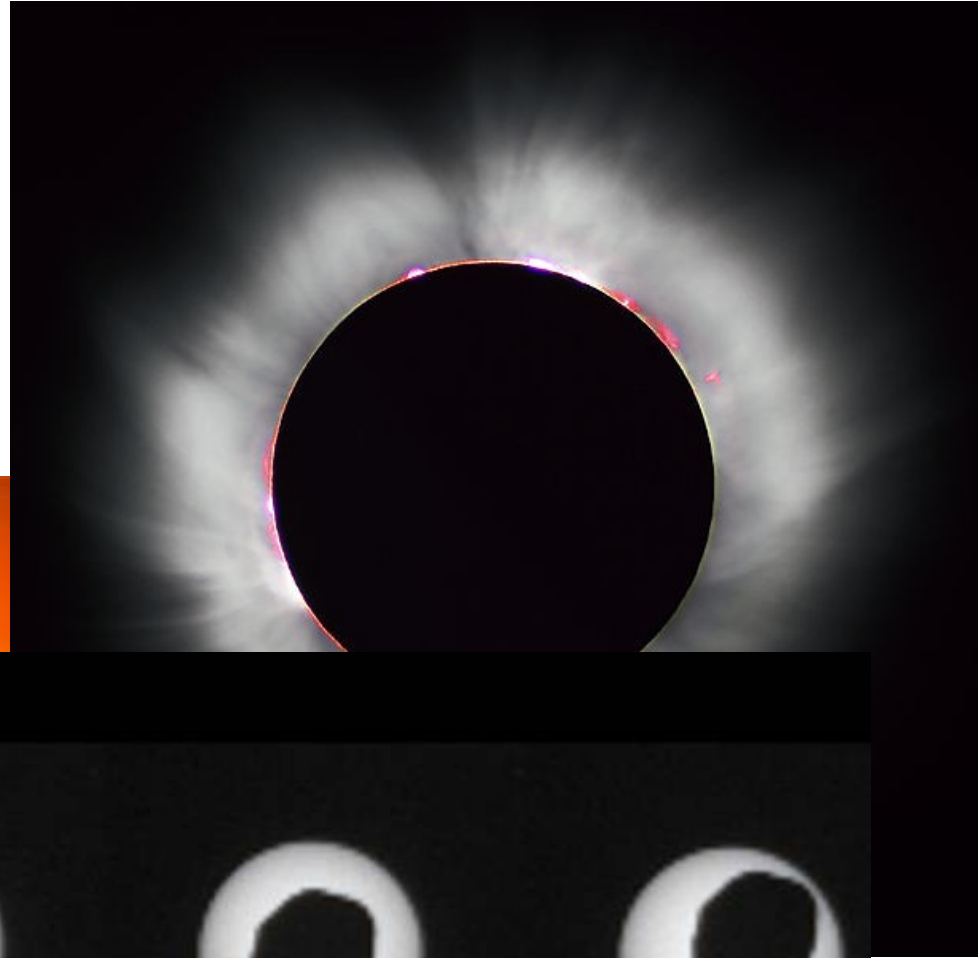## Total Lunar Eclipse, 2008

What's wrong with the labels?

Solar Eclipses!
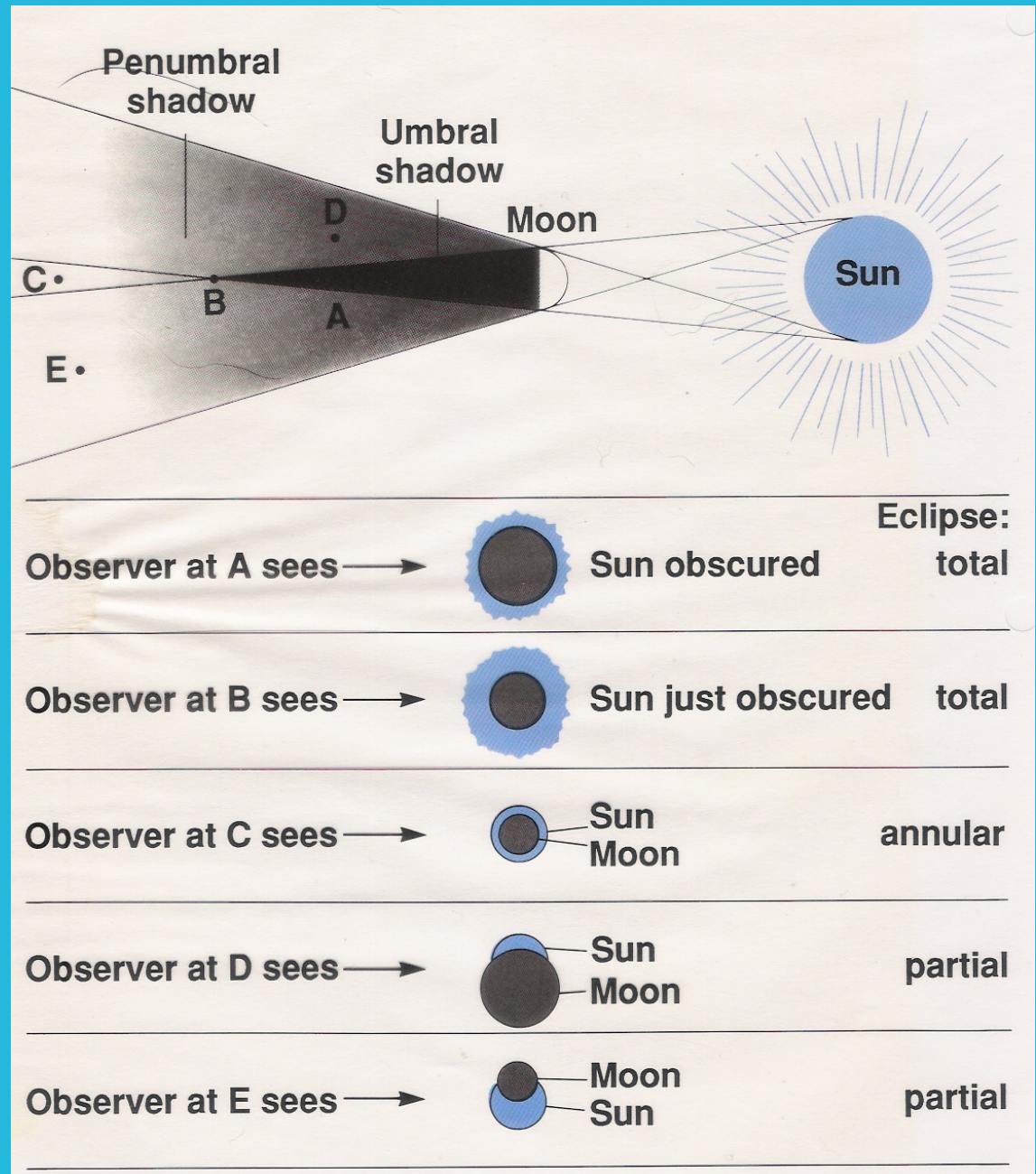
Total, 1999

Annular 1994

Phobos eclipses Sun, Aug 17, 2013

Solar eclipses - Moon is between Earth and Sun

A-E = possible positions of the Earth

Solar eclipses - Moon is between Earth and Sun
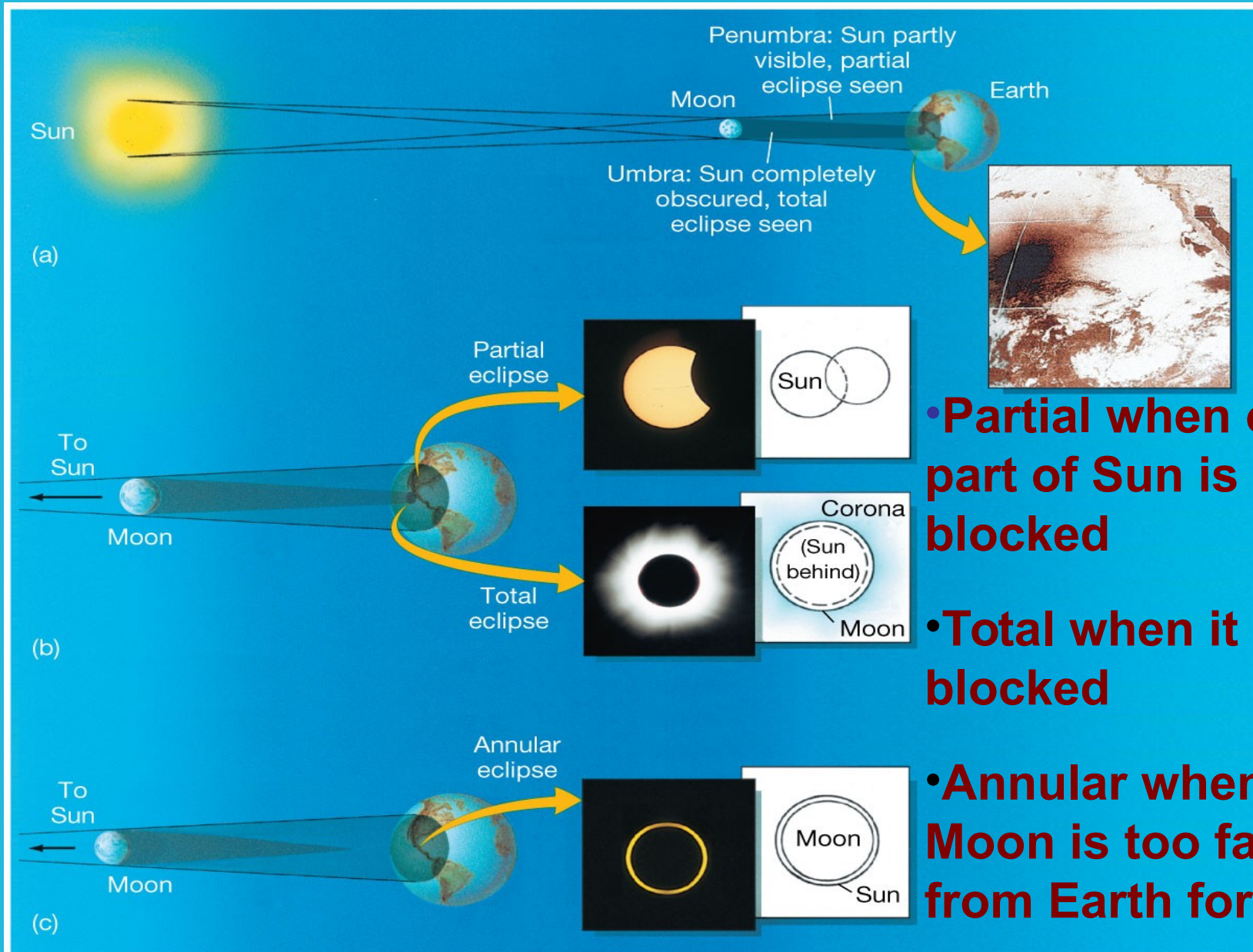
- **Partial when only part of Sun is blocked**

- **Total when it is all blocked**

- **Annular when Moon is too far from Earth for total**

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Solar Eclipse Paths

PATH OF ANNULAR ECLIPSE across Mexico, the United States, New Brunswick, and Nova Scotia.

May, 1994

Predicting Eclipses

Eclipses happen during *Eclipse Seasons* which are ...

34.5 days in duration (on average, range 31-37 d)
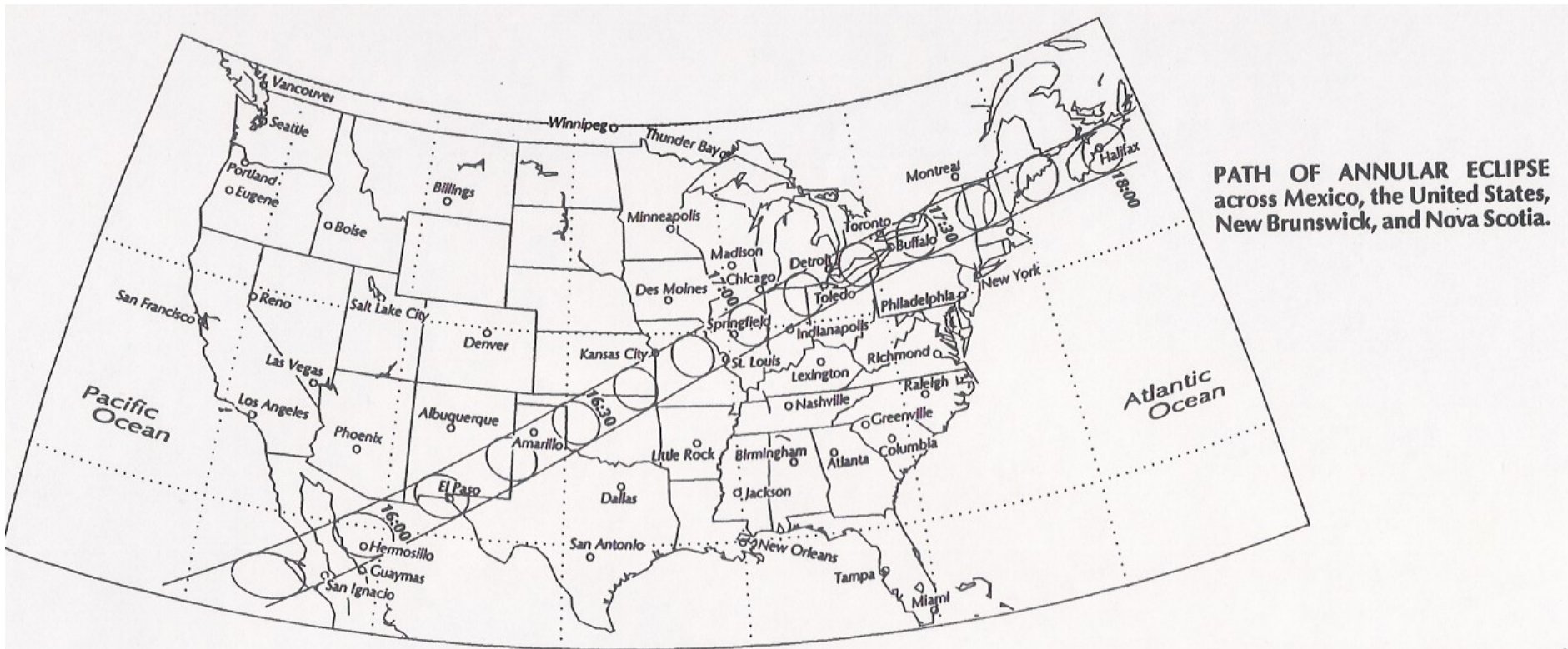**5.7 months apart**
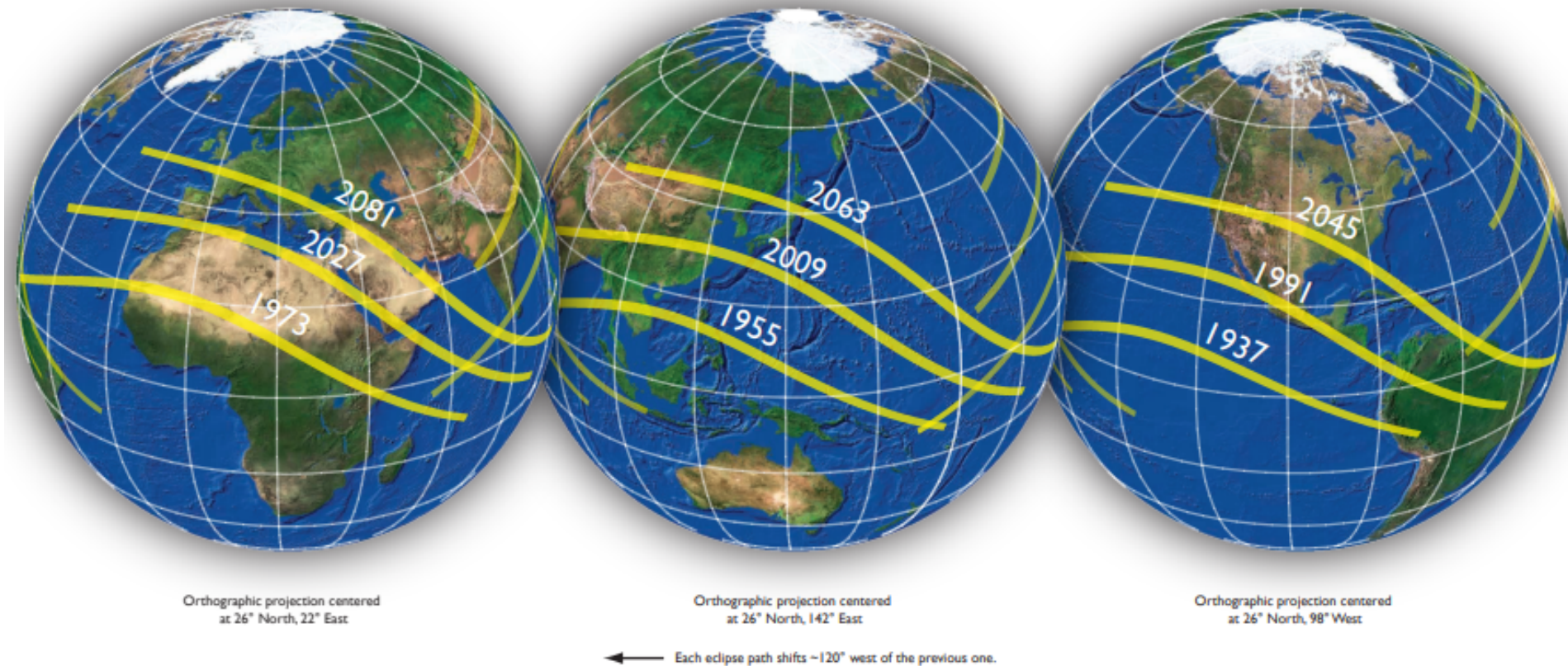**(2x5.7=11.4 months in a Draconic year)**

Every 18 yrs 11.33 days an eclipse of the same type will repeat on the same node (ascending or descending) and in the same part of the Moon's orbit (perigee, apogee, etc). This is a <u>saros</u>.

Every 54 yrs 34 days, an eclipse will repeat as above but also on about the same place(s) on Earth.
This is an exeligmos.

Predicting Eclipses

Saros 136

Orthographic projection centered
at 26° North, 22° East

Orthographic projection centered
at 26° North, 142° East

Orthographic projection centered
at 26° North, 98° West

◄— Each eclipse path shifts ~120° west of the previous one.
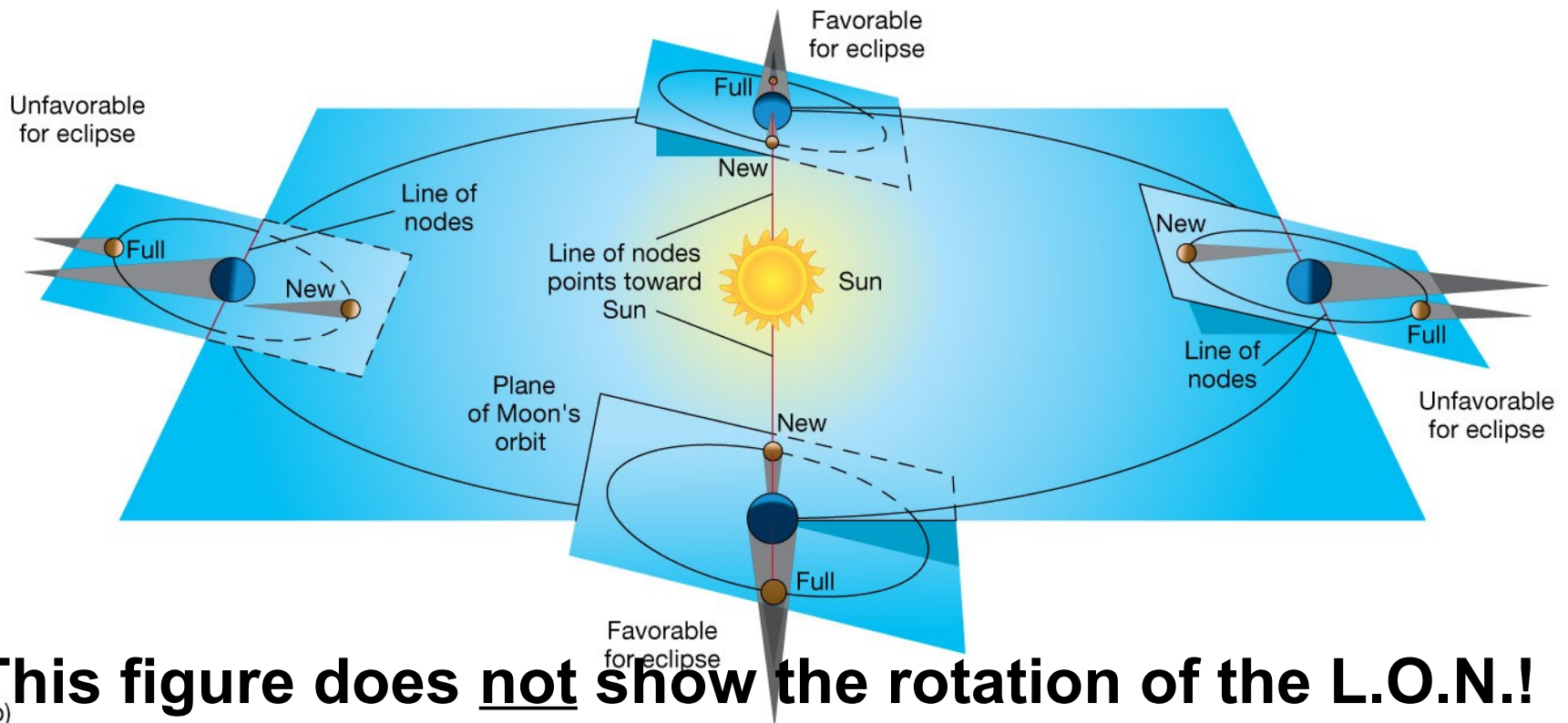
Saros 136 will produce 71 eclipses over 1262 yrs (8part,6annul,6hyb,44tot,7part)

Predicting Eclipses

Lunar nodal precession period: 18.6 yrs for the L.O.N. to rotate CW. Draconic year 346.6 days
Lunar apsidal precession period: 8.85 yrs for the line between perigee and apogee to rotate CCW.

This figure does not show the rotation of the L.O.N.!

1.5 Predicting Eclipses

J F M A M J J A S O N D

1990 91 92 93 94 95 96 97 98 99 2000 01 02 03 04 05 06 07 08 09 2010

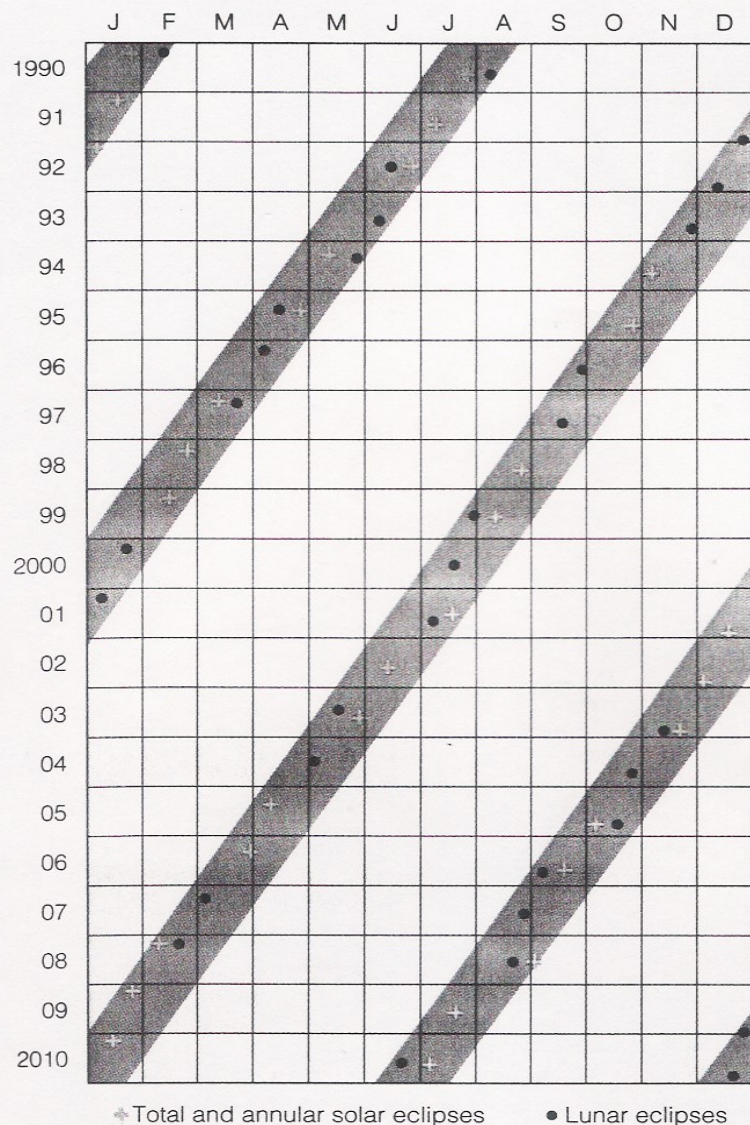✦ Total and annular solar eclipses   • Lunar eclipses

FIGURE 3-24

A calendar of eclipse seasons. Each year, the eclipse seasons begin about 19 days earlier. Any new moon or full moon that occurs during an eclipse season results in an eclipse. Not all eclipses are shown here.

Eclipse Seasons.

There are a minimum of 4, and a maximum of 7 eclipses per year (all types included).

There is a minimum of 2, and a maximum of 5 lunar eclipses per year. Same for solar.

A lunar and solar eclipse are often 2 weeks apart.

**Ohio's next solar eclipses:
Oct 14, 2023 - Annular
Apr 8, 2024 – Total**

1.5 Predicting Eclipses

<u>Total</u> solar eclipses occur *somewhere* on Earth about 2 times every 3 years (0.67/year).

Total solar eclipses happen at a given location (like a small town) about once every 370 years, on average. Some spots will have to wait over 1000 years for their next total solar eclipse, while other lucky spots have two separated by 1.5 years.

Total lunar eclipses happen at a given location about once per year because a TLE can be seen by half of the Earth at a given moment.

1 Saros = 6585.32 d (18 yrs 11 d 8 hrs)
       ~ 223 synodic months
       ~ 239 anomalistic months
       ~ 242 draconic months

1.6 The Measurement of Distance

Triangulation:
Measure baseline and angles, can calculate distance

Tree

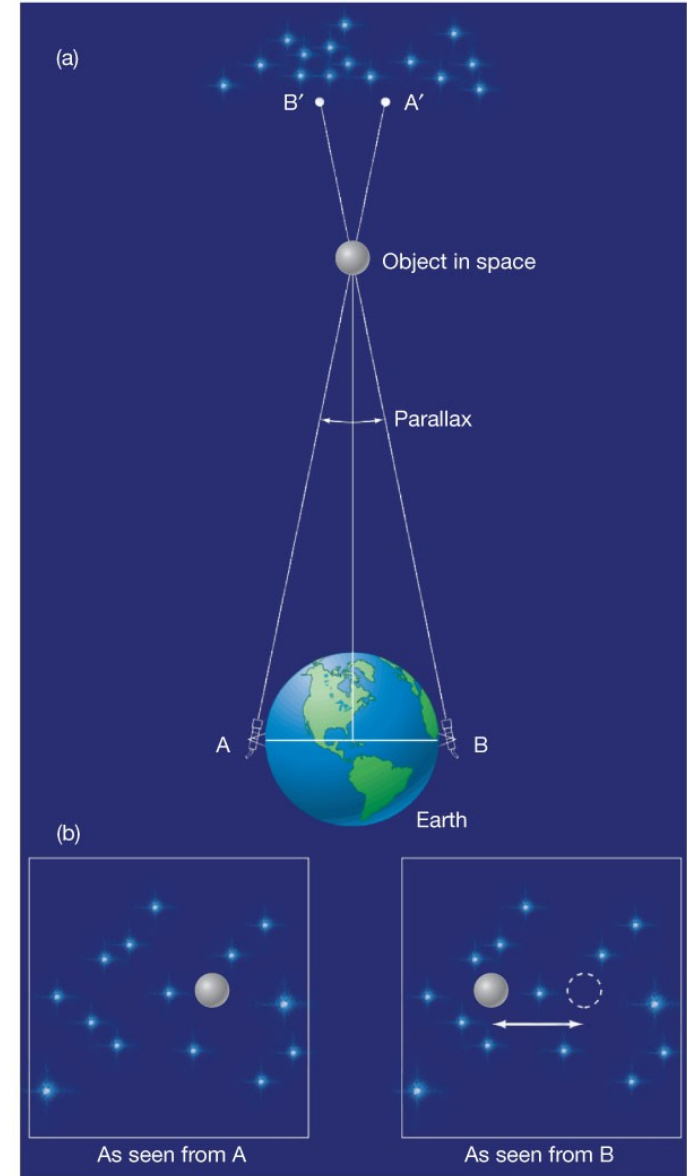Distance to object

90°

A

B

Baseline
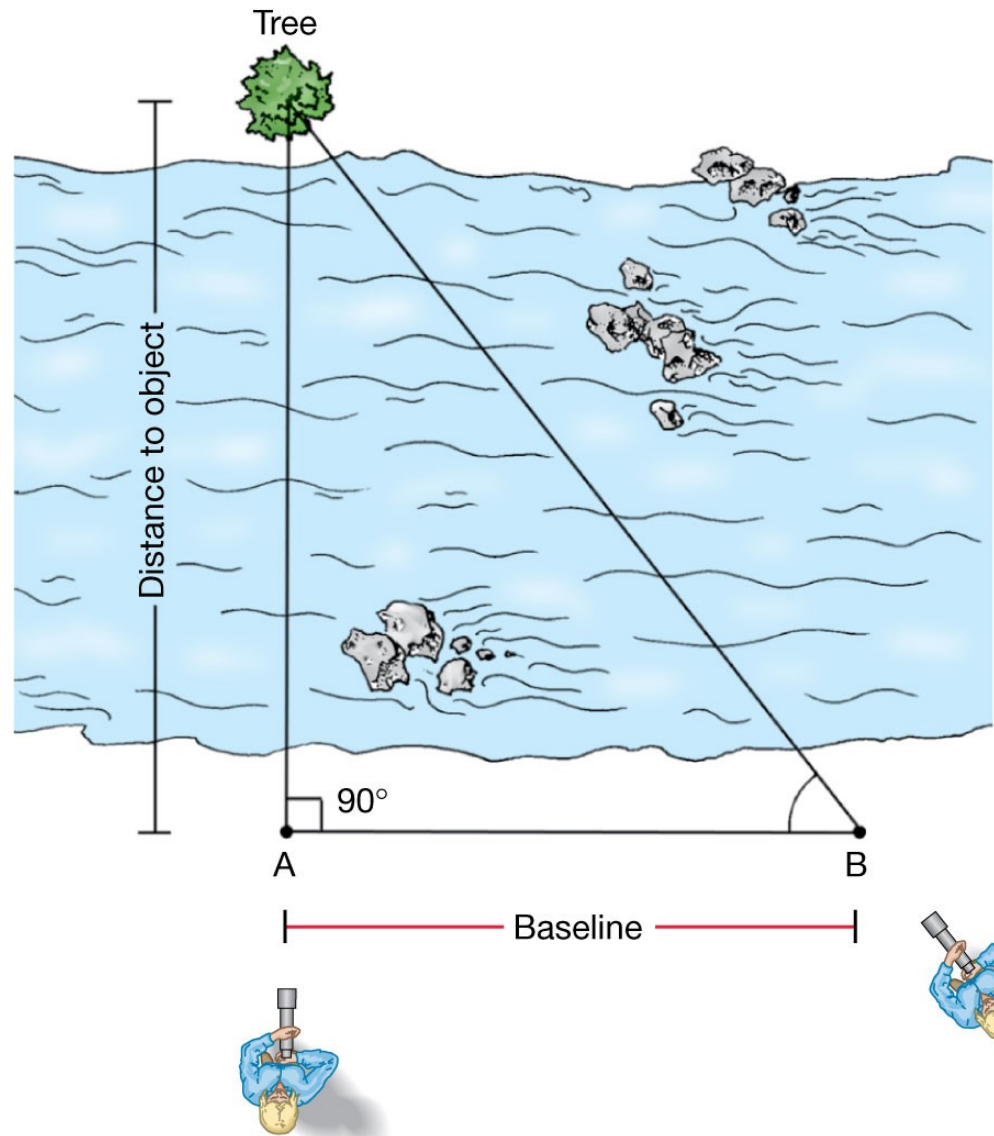
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1.6 The Measurement of Distance

Parallax: Similar to triangulation, but look at apparent shift of object against distant background from two vantage points.

Change your POV to the object.
θ = LD/D becomes
parallax = Baseline/D

(a)

B' A'

Object in space

Parallax

A   B

Earth

(b)

As seen from A

As seen from B

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Summary of Chapter 1

- **Astronomy**: Study of the universe

- **Scientific method**: Observation, theory, prediction, observation, …

- Stars can be imagined to be on inside of **celestial sphere**; useful for describing location

- Plane of Earth's orbit around Sun is **ecliptic**; at 23.5° to celestial equator

- Tilt of Earth's axis causes **seasons**

- Moon shines by reflected light, has **phases**

Summary of Chapter 1 (cont.)

- **Solar day ≠ sidereal day**, due to Earth's revolution around Sun

- **Synodic month ≠ sidereal month**, also due to Earth's revolution around Sun

- **Tropical year ≠ sidereal year**, due to precession of Earth's spin axis

- **Eclipses of Sun and Moon** occur due to alignment; only occur occasionally as orbits are not in same plane

- Distances can be measured through **triangulation** and **parallax**