Chapter 1:

The Cycles Of the Sky

Astronomy

Chapter 1: The Cycles of the Sky

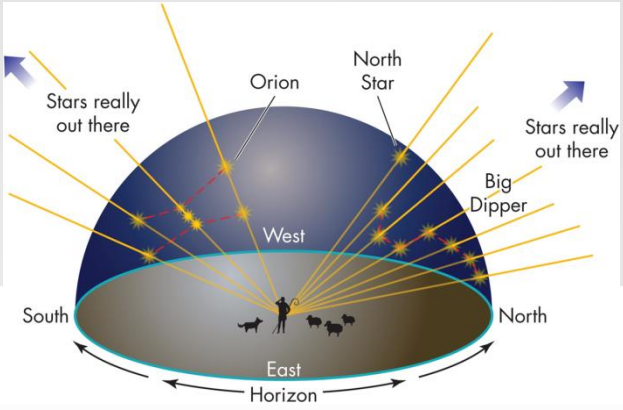
Topics

1. **The Celestial Sphere**
   - Constellations
   - Daily Motions of the Sun and Stars
   - Annual Motion of the Sun
   - The Ecliptic and the Zodiac
2. **The Seasons**
   - Solstices, Equinoxes, and the Ecliptic's Tilt
   - Tracking the Sun's Changing Position

1. The Celestial Sphere

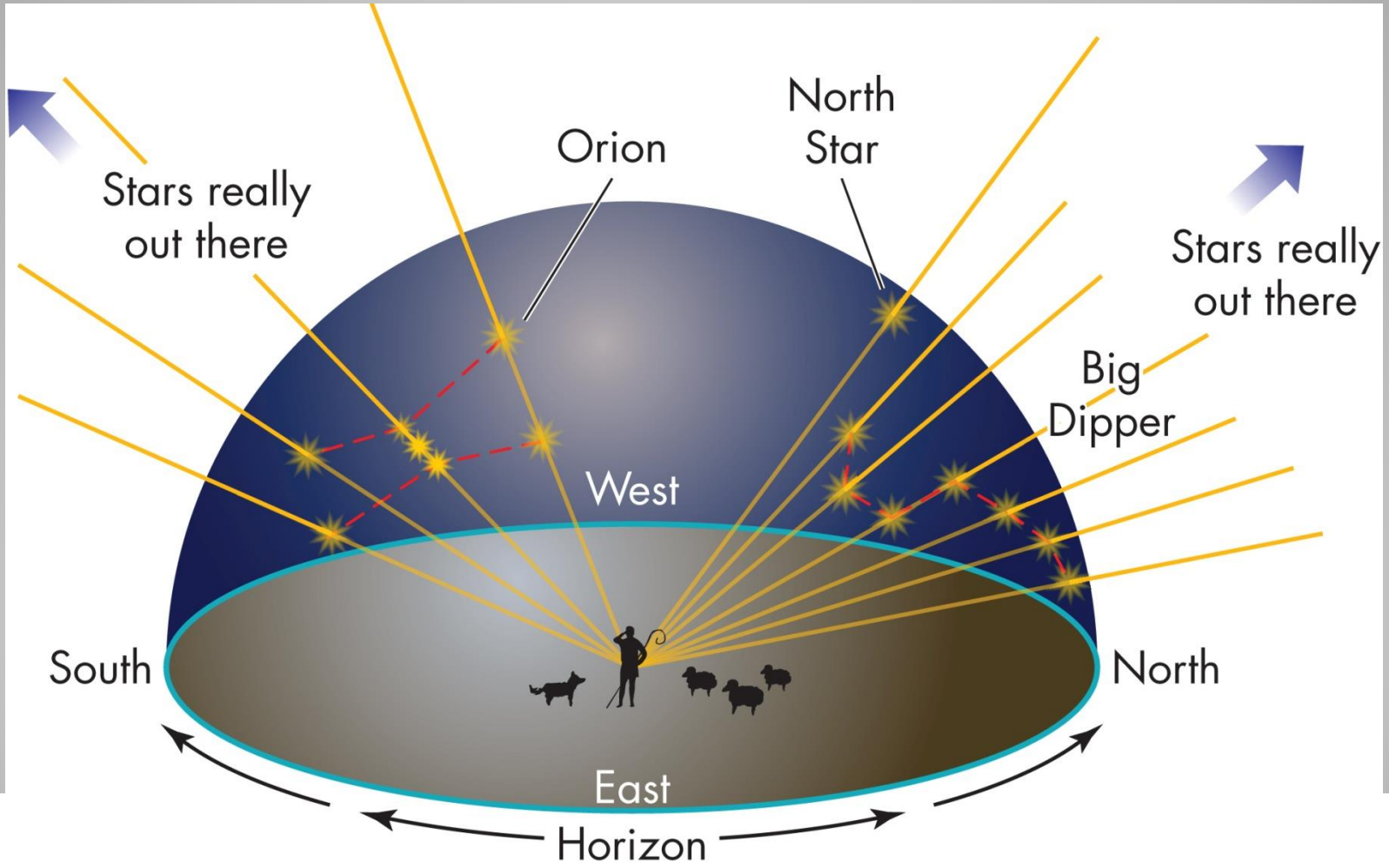
Introduction

- Remember, stars are huge distances away that we can't get any sense of their true 3D arrangement in space when we view them
- When looking from Earth and studying the sky, we can simply assume they're all the same distance away (for now)
- The sky above can be seen as a "dome"
- Horizon – where the sky meets the ground along a horizontal circle



1. The Celestial Sphere

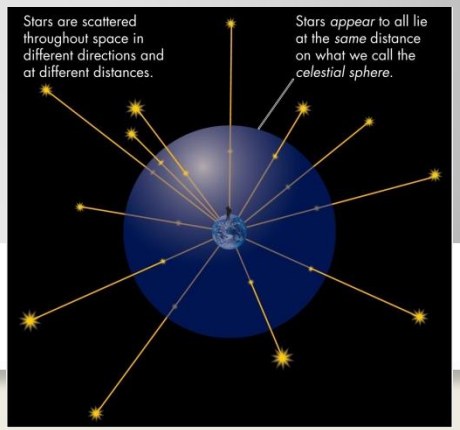
Introduction



1. The Celestial Sphere

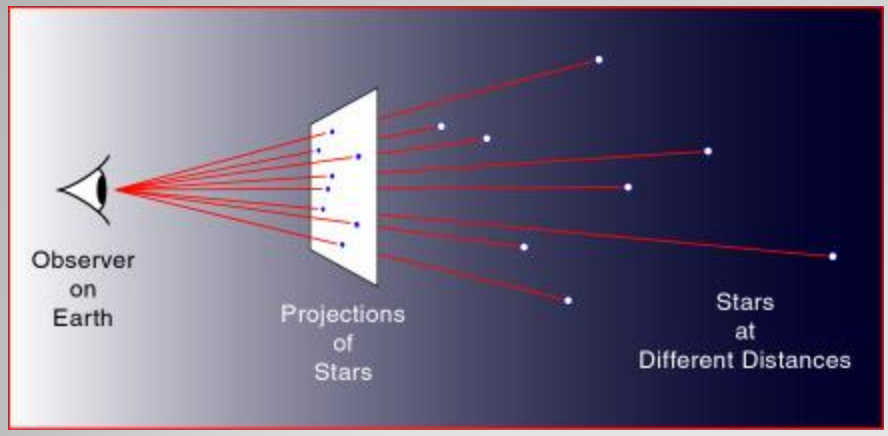
Introduction

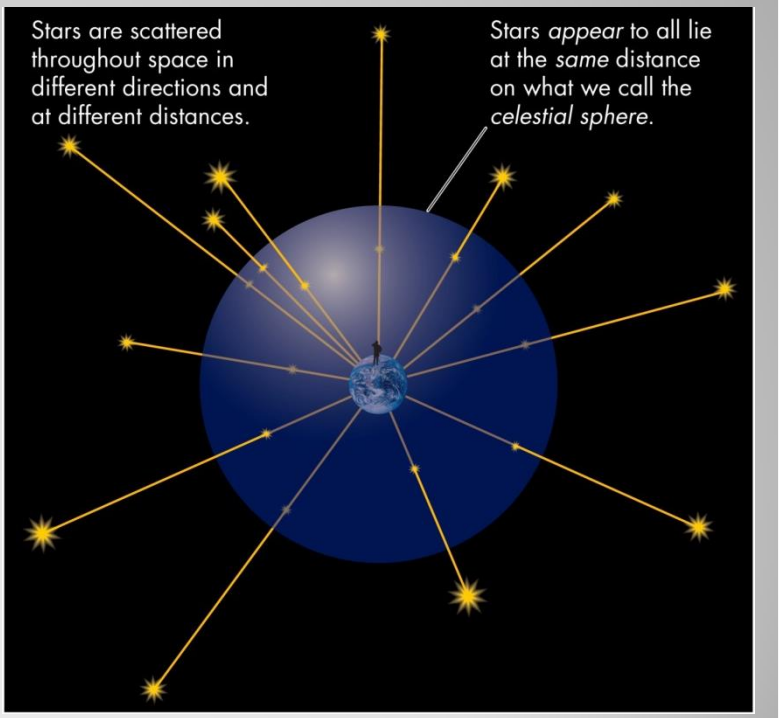
- Celestial Sphere – an imaginary sphere surrounding the Earth representing the sky
  - *Celestial* means "sky" or "space"
  - We only see half of the celestial sphere at one time
    - The ground blocks the other half
  - Our "dome" is our half of the celestial sphere
- Reality is that stars are at all different distances from Earth, but we see a 2D prospective, making them all seem the same distance away from Earth's surface



1. The Celestial Sphere

Introduction





1. The Celestial Sphere

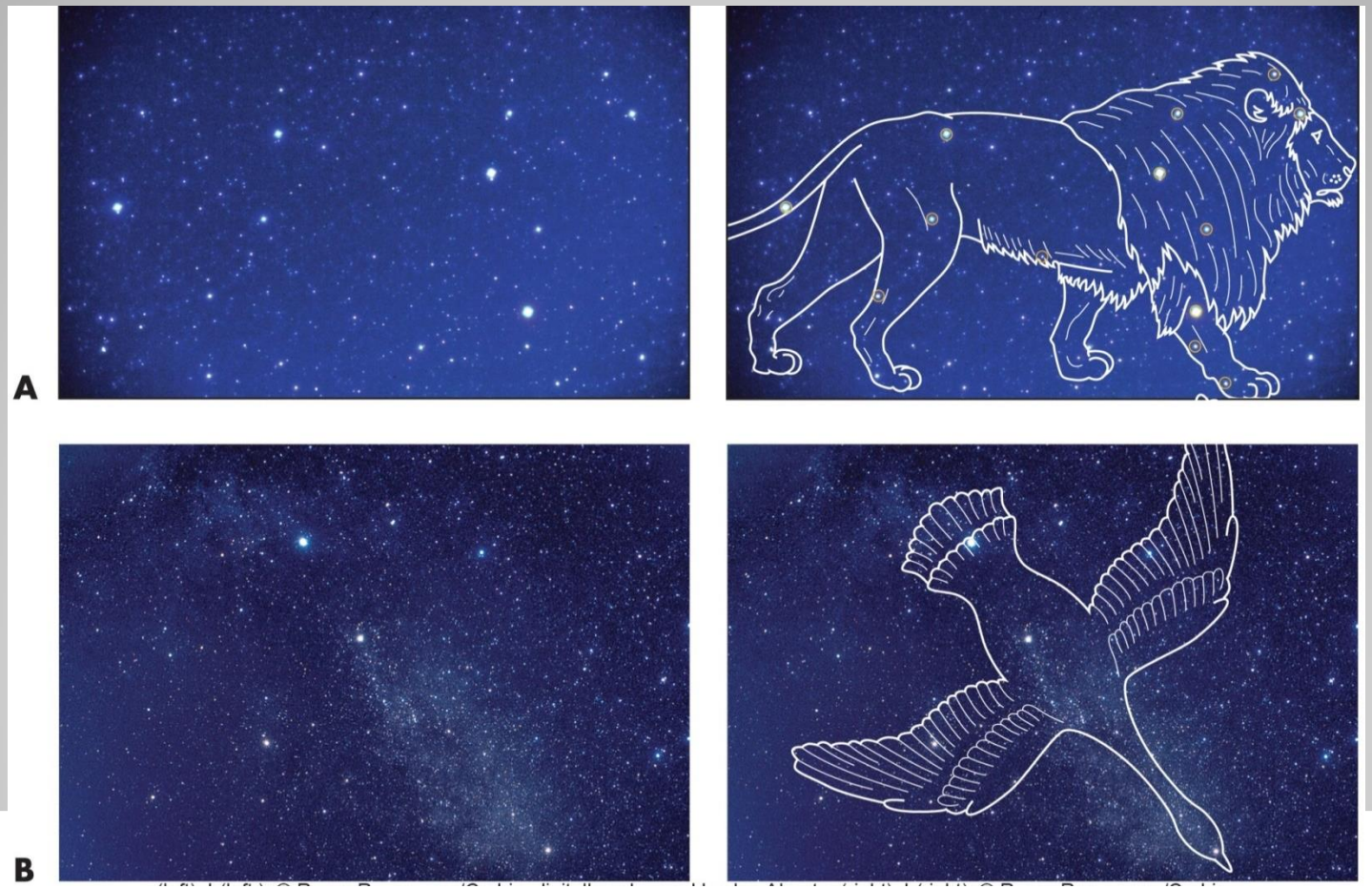
Constellations

- Naturally, we humans seek order or look for patterns in what we see
- When ancient people looked at the sky, they noticed that the stars form fixed patterns on the celestial sphere
- Constellation – a grouping of stars in the night sky from one prospective
- Astronomers of the IAU divided the night sky into 88 constellations
  - Some of these resemble animals and other mythological creatures, but others are not recognizable by their shape and name combo

1. The Celestial Sphere

Constellations

Constellations Leo (A) and Cygnus (B)



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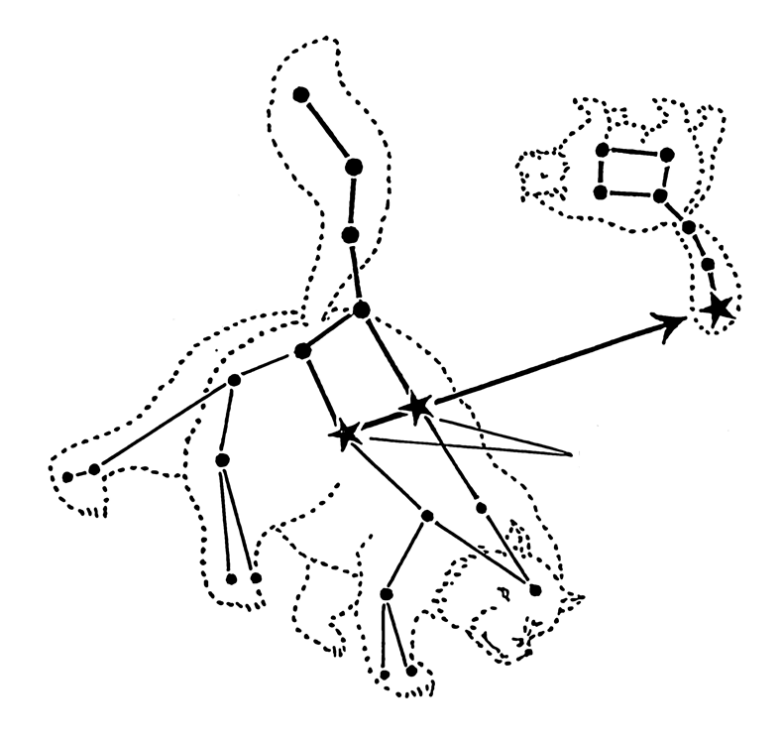
Constellations

- Asterism – less formally defined group of stars in a constellation
  - Ex: the big dipper!
  - It's part of the constellation Ursa Major



1. The Celestial Sphere

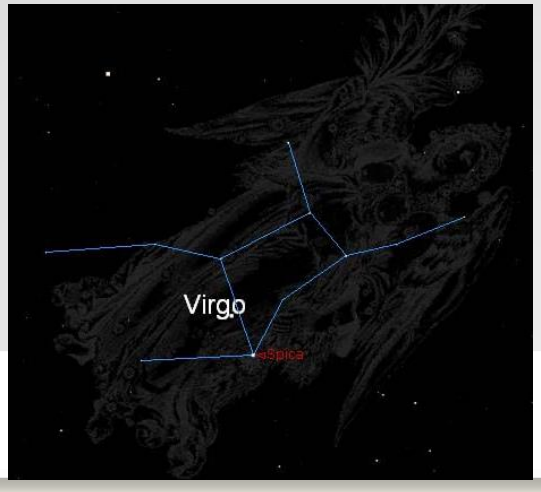
Constellations

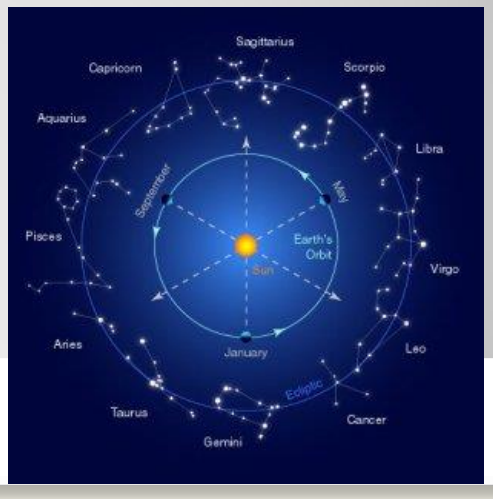
- All stars move through space, but as seen from Earth, their positions change very slowly
- This takes tens of thousands of years to make any noticeable shift in position in the sky
- When we study the celestial sphere, we assume they don't move
- The patterns we see today are the same as the patterns seen by ancient civilizations

1. The Celestial Sphere

Constellations

- Some were named based on navigation and growing seasons
  - Ex: Aquarius and Pisces are two constellations visible to sailors at the beginning of the stormy winter months so they were named based off of those dangerous waters
  - Ex: Virgo (named after the goddess *Proserpine*) was named as it was for the harvest season as it looked like she was holding a sheaf of grain





1. The Celestial Sphere

Daily Motions of the Sun and Stars

- When you look in the night sky, stars will rise along the eastern horizon, move across the sky, and set over the west horizon just like the Sun does
- Constellations will rise and set in their fixed patterns just like the individual stars
- This movement is a big optical illusion
  - Earth is the one rotating, not the constellations or Sun in the sky
  - Very similar to driving down the highway in the car
    - The trees and view outside zips past your window making it seem like it's moving behind you really fast when in reality it's not moving, you are and in the opposite direction

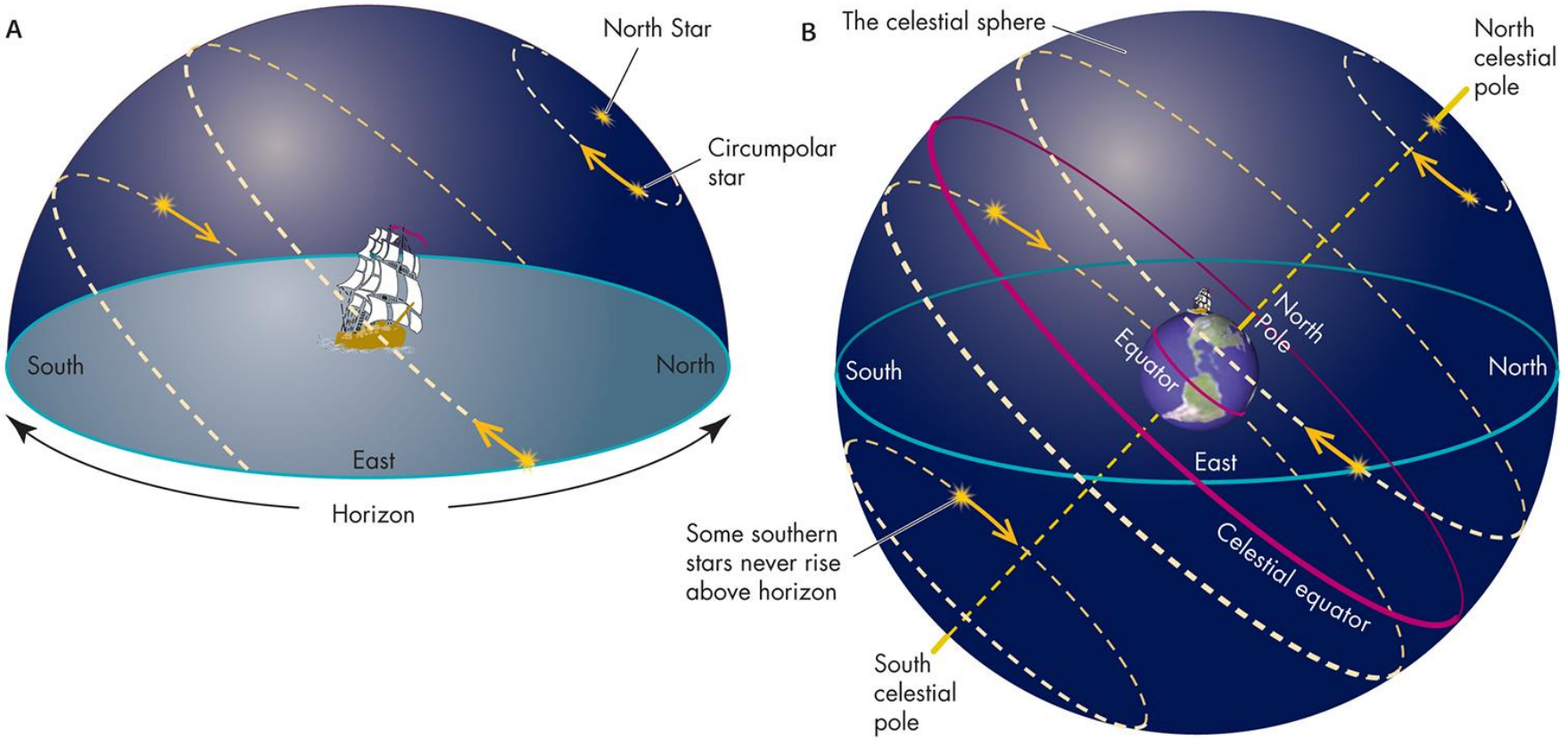
1. The Celestial Sphere

Daily Motions of the Sun and Stars

- There are two points that don't move on the celestial sphere: celestial poles
- Celestial Pole – an imaginary point on the celestial sphere directly above the Earth's North or South Pole
  - We can "see" the north celestial pole, the southern one we cannot
- The Earth rotates (spins) on it's axis that runs through the poles… This is why the celestial ones don't move
- Because of how we rotate, the sky and stars in it move counterclockwise around the north celestial pole
  - It's backwards, just like the driving example
  - Or… the sky moves westward because we move eastward

1. The Celestial Sphere

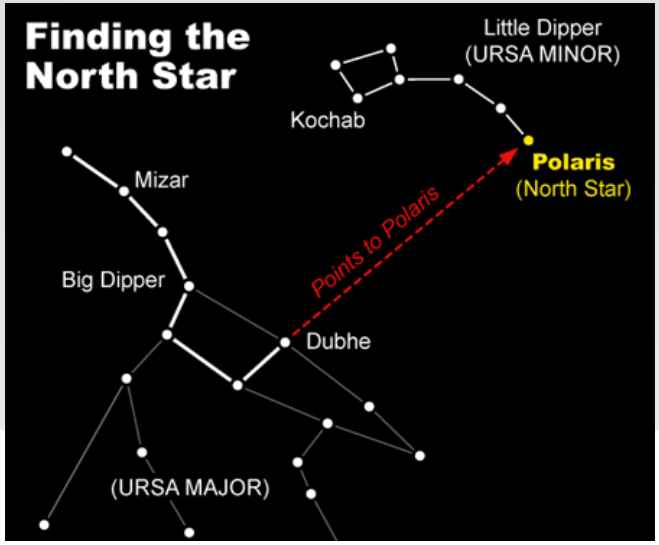
Daily Motions of the Sun and Stars



1. The Celestial Sphere

Daily Motions of the Sun and Stars

- Because the north celestial pole is above the North Pole, it sets the direction for the true north (or cardinal north) direction
  - A fairly bright star, *Polaris*, sits very close to it and because of that is commonly known as the North Star
  - The south celestial pole doesn't have one



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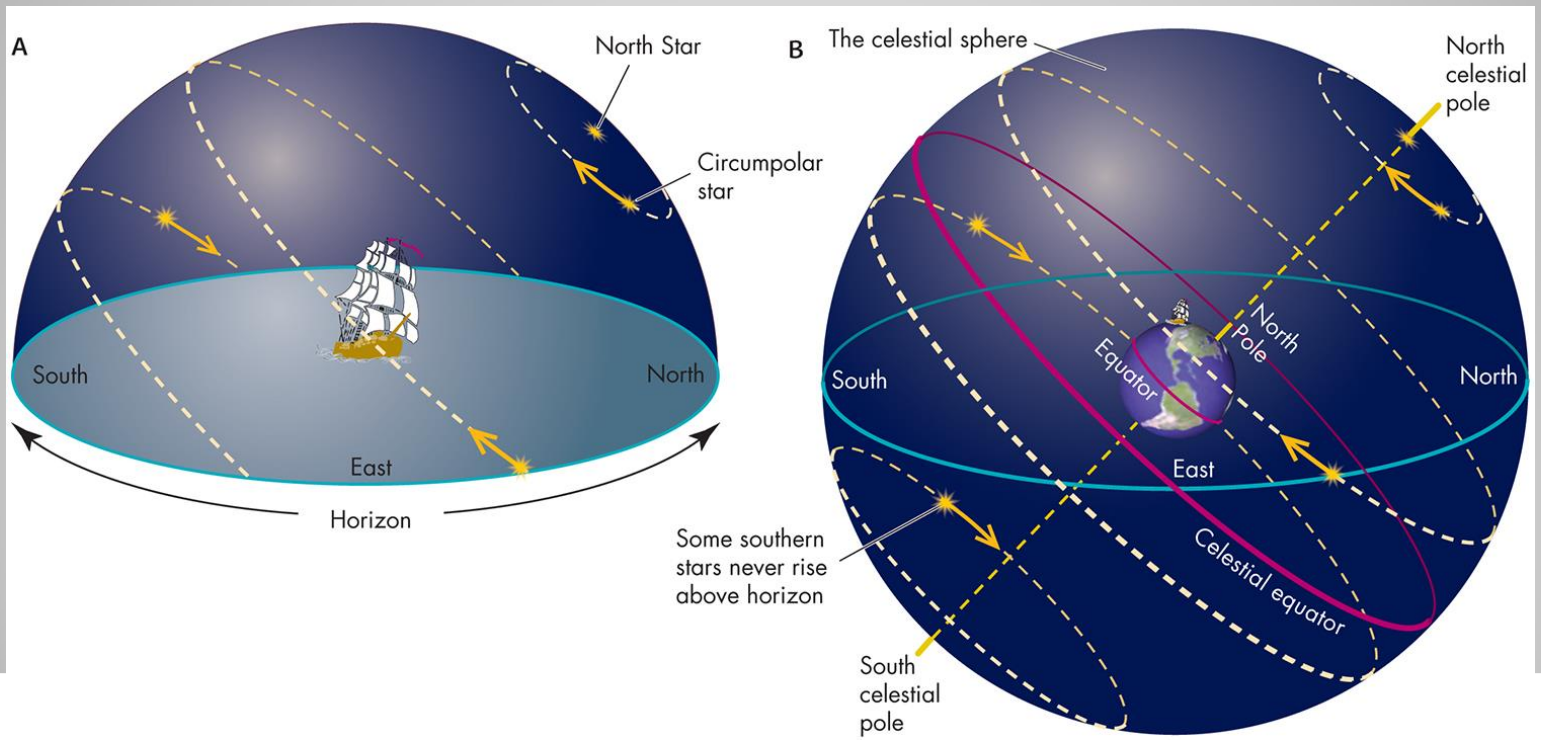
Daily Motions of the Sun and Stars

- Celestial Equator – an imaginary line on the celestial sphere lying exactly above the Earth's equator
  - This divides the northern and southern hemispheres



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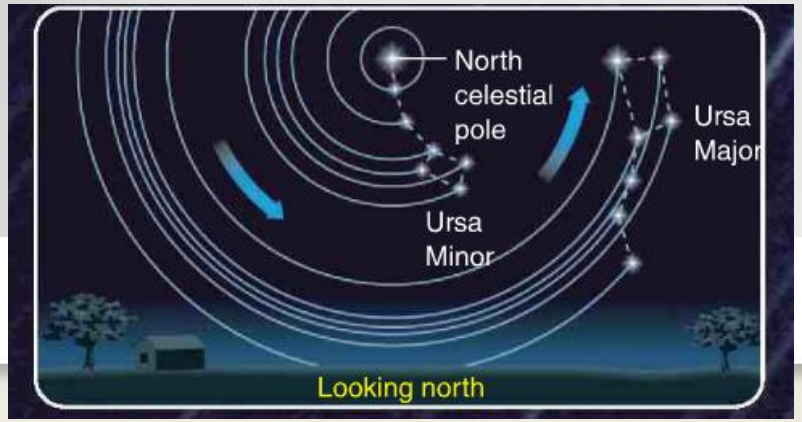
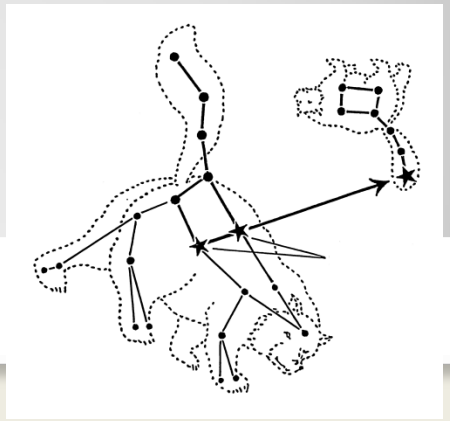
Daily Motions of the Sun and Stars

- Circumpolar Constellations – stars and constellations that circle around a celestial pole and never rise or set over the horizon
  - Ex: Ursa Major and Ursa Minor are two of the northern circumpolar constellations
- From the northern hemisphere there are southern circumpolar constellations we will never see
  - same with the southern hemisphere, they'll never see the dippers





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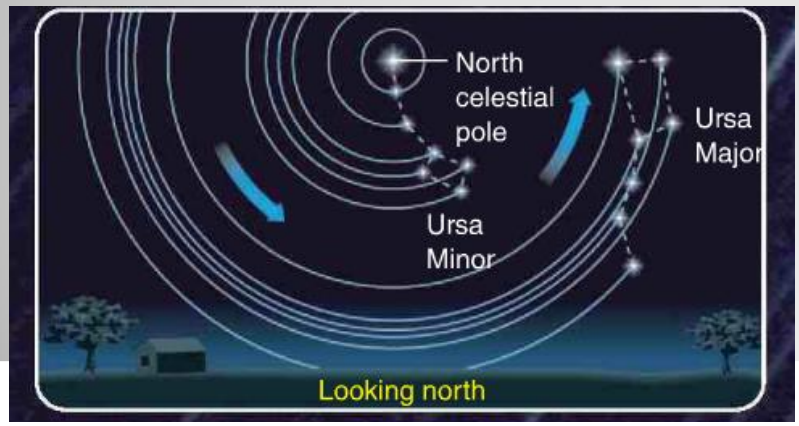
Daily Motions of the Sun and Stars

- Star Trails – streaks that show the pathway stars traveled in our vision of the sky
  - Physical star trails are computer generated in most cases…
  - Depending on where stars are in our line of sight will depend on how fast/far they travel throughout the night
    - Stars closer to the celestial poles won't travel as far as those near the celestial equator



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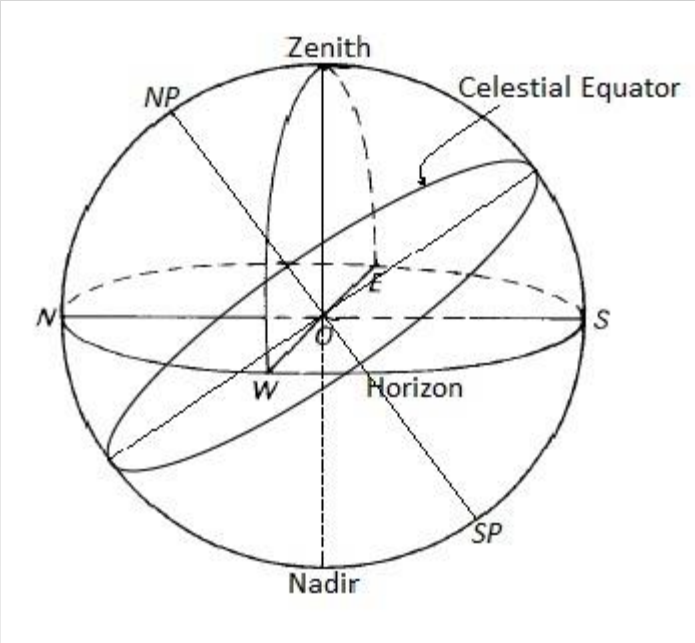
Daily Motions of the Sun and Stars

- Zenith – the point on the celestial sphere that lies directly overhead at YOUR location
- Nadir – the point opposite of the zenith
  - We can't see this



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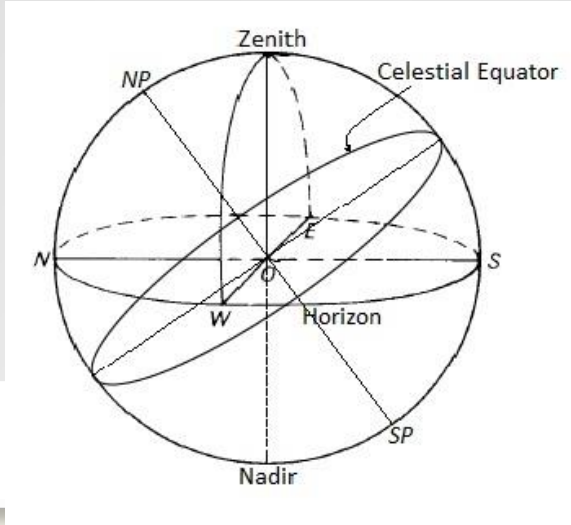
Daily Motions of the Sun and Stars

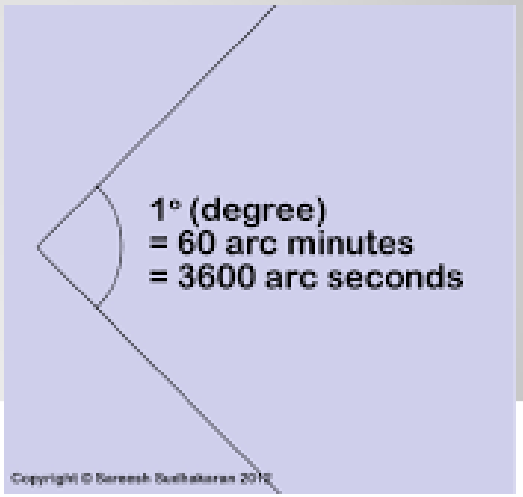
- North Point – point on the horizon closest to the north celestial pole (Cardinal North)
- South Point – point on the horizon closest to the south celestial pole (Cardinal South)
- East/West Points – points that are halfway between north and south where the equator meets the horizon (Cardinal East/West)



1. The Celestial Sphere

Daily Motions of the Sun and Stars

- Astronomers measure angular distances across the sky as angles and express them as:
  - Degrees
  - Arc minutes
  - Arc seconds
- Angular Distance – the distance between two lines extending from your eye to the two objects
  - Degrees is the standard
  - Arc minute – 1/60th of a degree
  - Arc second – 1/60th of an arc minute



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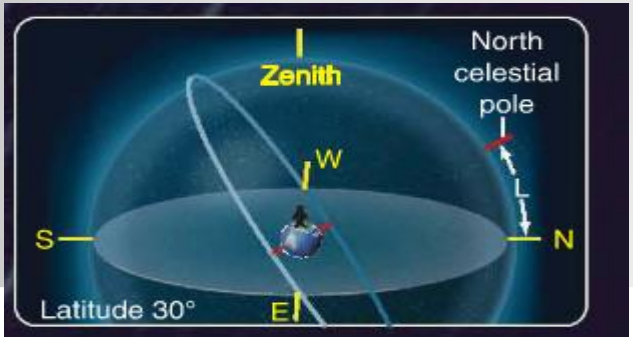
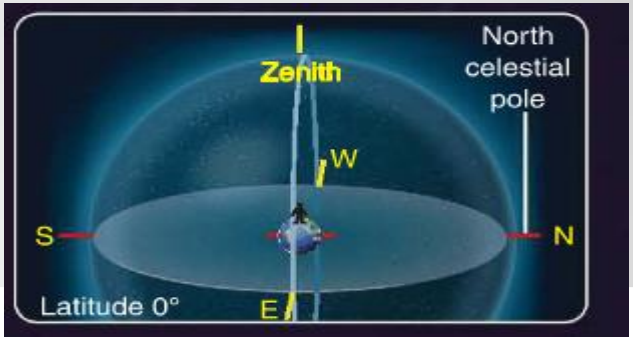
Daily Motions of the Sun and Stars

- What you see in the sky depends distinctly on your latitude
- The angular distance of from the north or south celestial pole will always equal your latitude
  - Ex: 40° latitude = a 40° angle from the location of the north celestial pole to the north point on the horizon
  - Ex: 0° latitude = the equator where there would be a 0° angle between the celestial poles and the points on the horizon

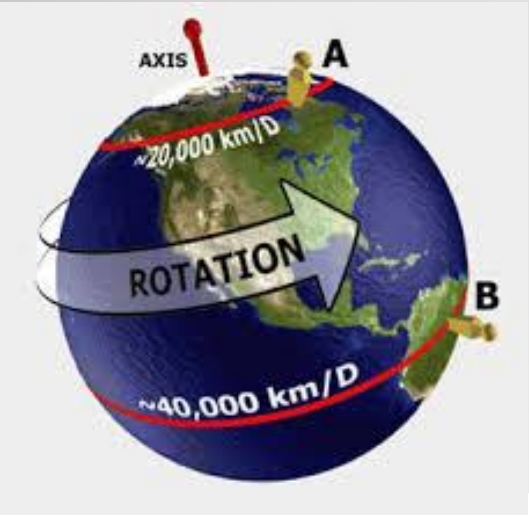


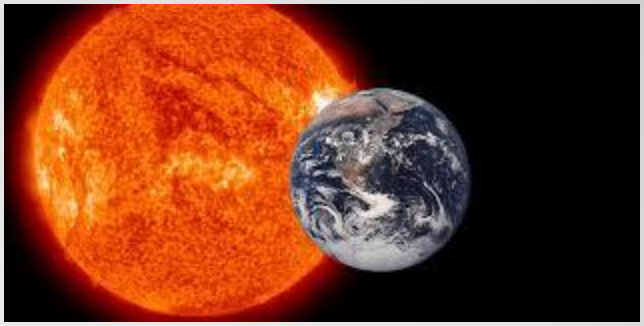


1. The Celestial Sphere

Annual Motion of the Sun

- Rotation – turning of a body on its axis
  - Earth spinning on its axis in 24 hours
- Revolution – the motion of a body around a point outside of that body
  - Earth moving around the Sun or the Moon moving around Earth

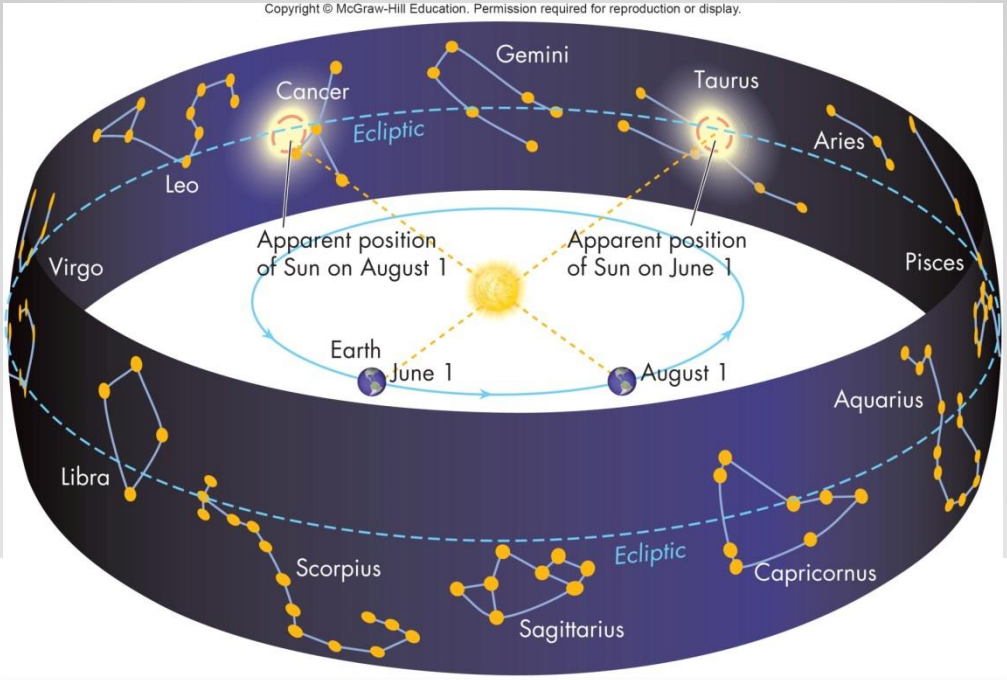




1. The Celestial Sphere

Annual Motion of the Sun

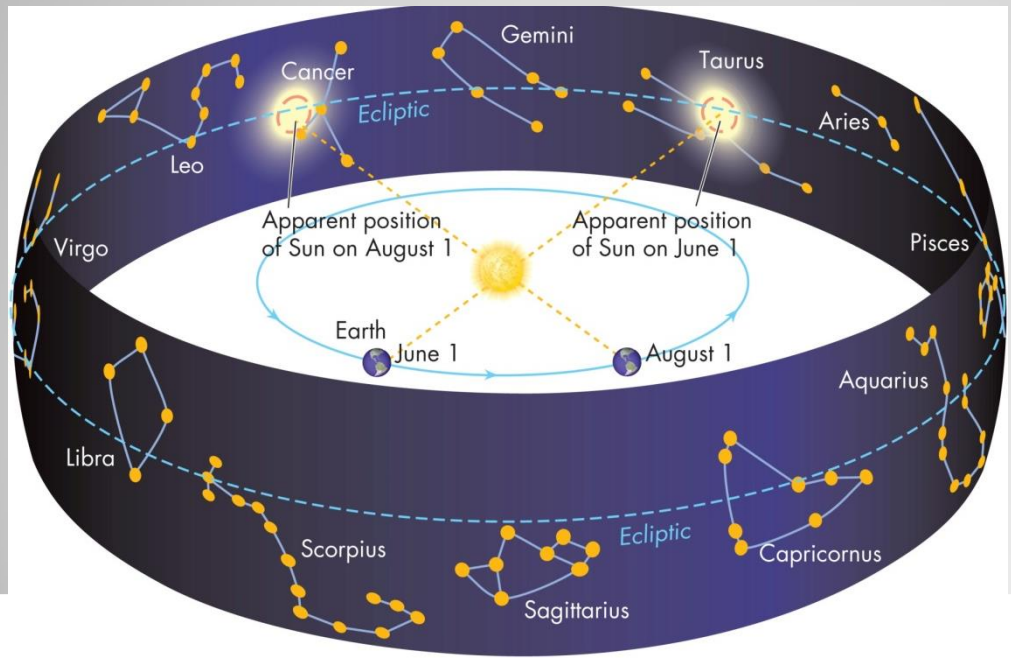
- If you compare the sky at the same time each evening for a few months, you'll see that different constellations are visible
- This is caused by the Earth's movement around the Sun throughout the year

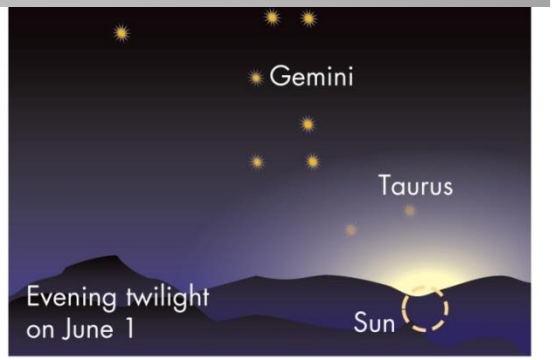


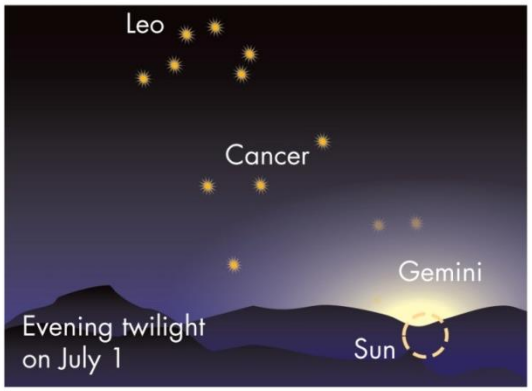
1. The Celestial Sphere

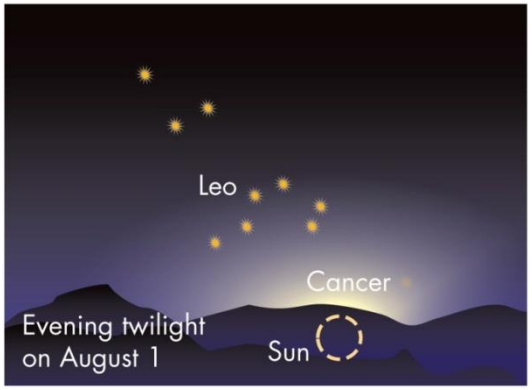
Annual Motion of the Sun

- Stars rise almost 4 minutes earlier than the day before due to this





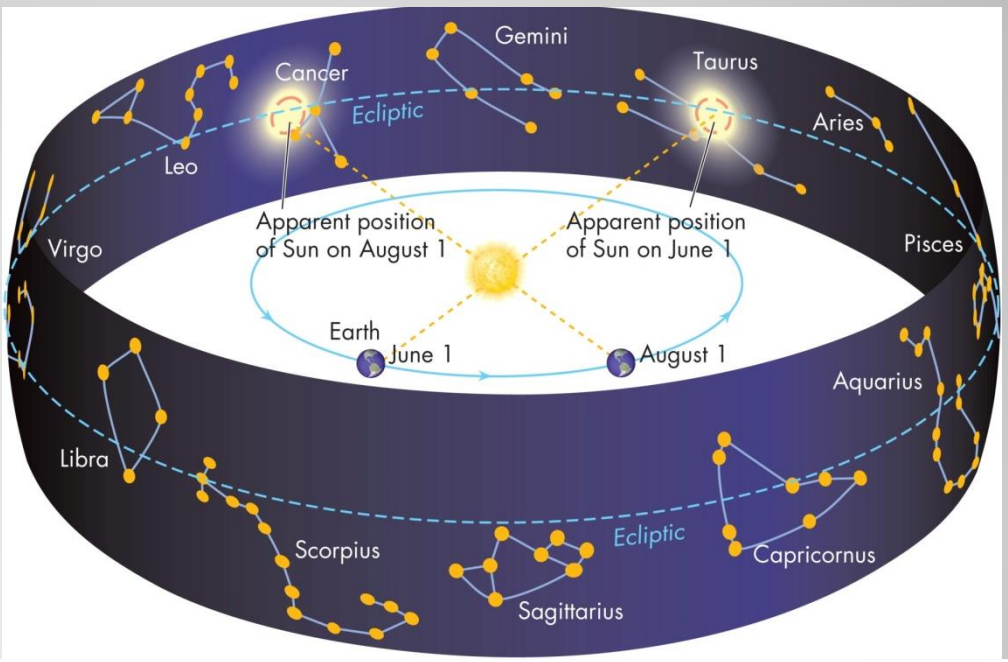




1. The Celestial Sphere

The Ecliptic and the Zodiac

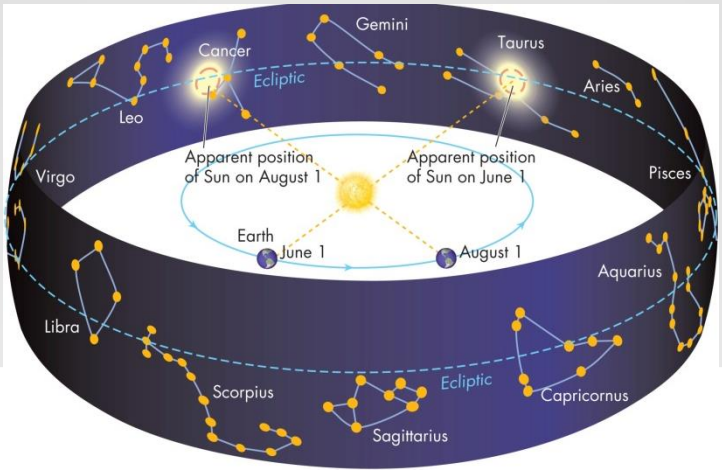
- Ecliptic – the path that the Sun appears to make around the celestial sphere as the Earth moves along its orbit
- This ecliptic is where the zodiacs came from
- The Sun passes through 12 main constellations… the zodiacs
  - Aries
  - Taurus
  - Gemini
  - Cancer
  - Leo
  - Virgo
  - Libra
  - Scorpius
  - Sagittarius
  - Capricornus
  - Aquarius
  - Pisces



1. The Celestial Sphere

The Ecliptic and the Zodiac

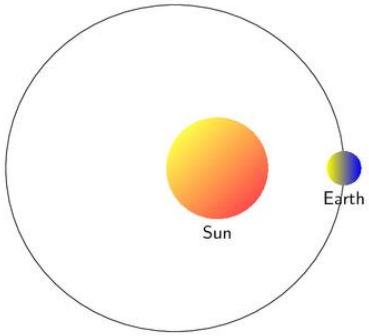
- The zodiacs fall under *astrology* which is defined as a pseudoscience and NOT affiliated with astronomy
  - Sorry horoscope people…
  - It was thought that personality characteristics were associated to which constellation figure was in the sky at the time
  - Stars do move and shift over 1000s of years so the original dates of the horoscopes and zodiacs are, in fact, incorrect (sorry again)



2. The Seasons

Introduction

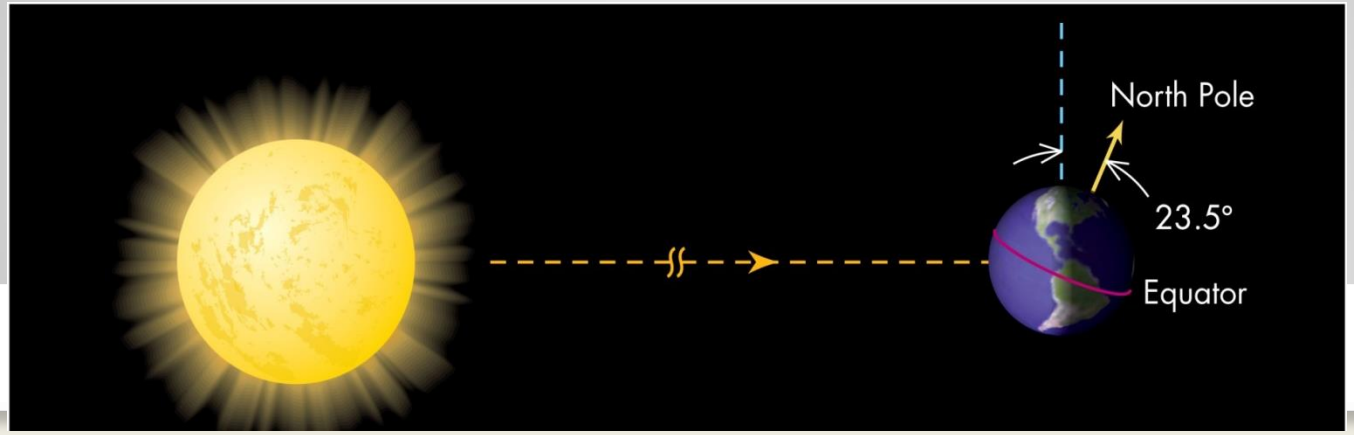
- The Earth's orbit (revolution) around the Sun is oval and a bit off center
- There is a time where it is closer to the Sun than other times of the year
- *Common misconception*: the seasons are directly related to Earth's elliptical around the Sun
  - That summer occurs when the planet is closest to the Sun and winter occurs when it is farthest away



2. The Seasons

Introduction

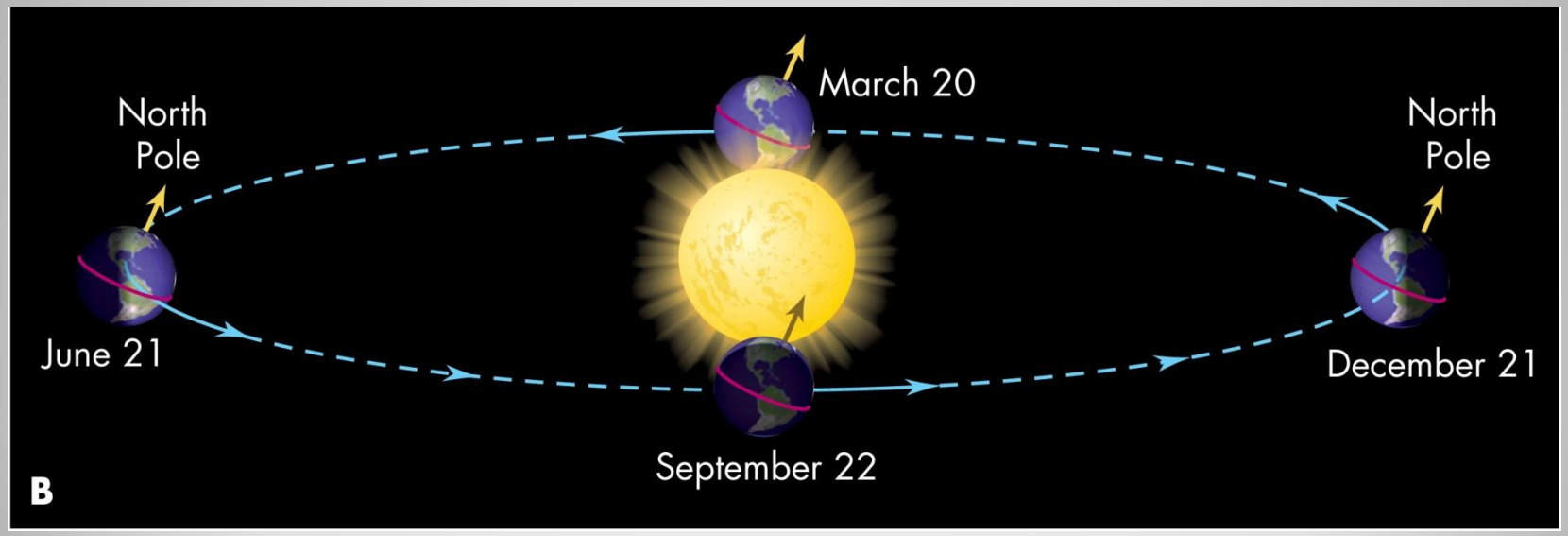
- The opposite is true (in the northern hemisphere)
- Our summer season is when we are furthest from the Sun and our winter season is when we are closest to the Sun
- Reason? = axis tilt of 23.5°
- Rotation Axis – an imaginary line through the center of a body about which that body rotates (spins)
- Earth's rotation axis goes through each of the poles



2. The Seasons

Introduction

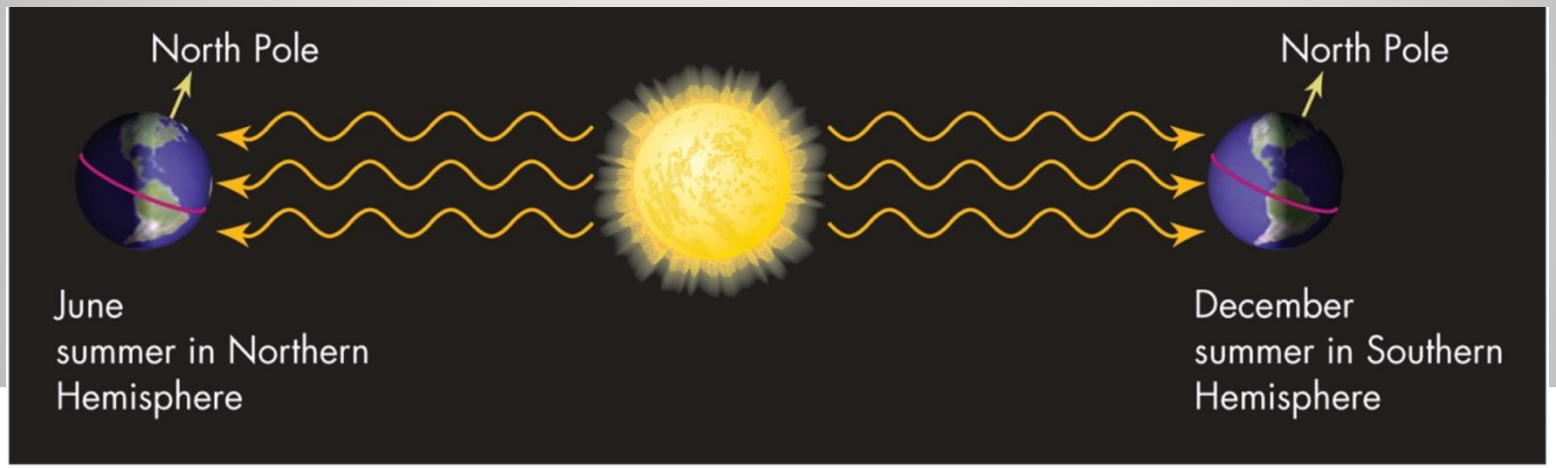
- The axis is NOT perpendicular to the orbit around the Sun
  - Meaning that the angle of the rotation axis will never change as it moves around the Sun



2. The Seasons

Introduction

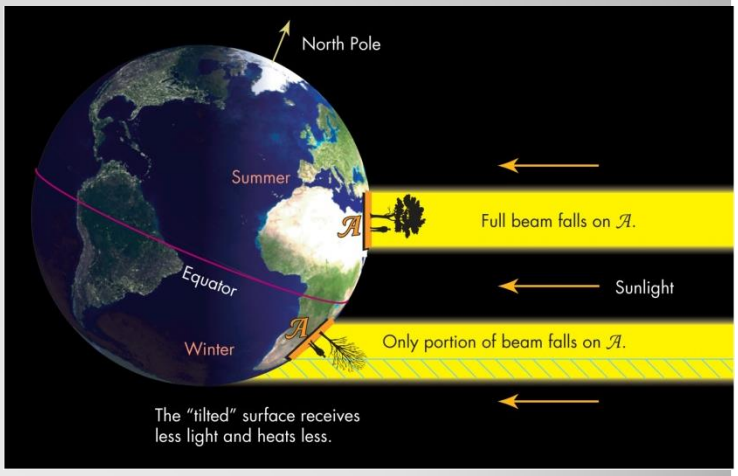
- Because this is constant, sunlight falls more directly on the northern hemisphere in June (and months around it) and more directly on the southern hemisphere in December (and months around it)
- This causes a variation of heat in each hemisphere at each time of the year



2. The Seasons

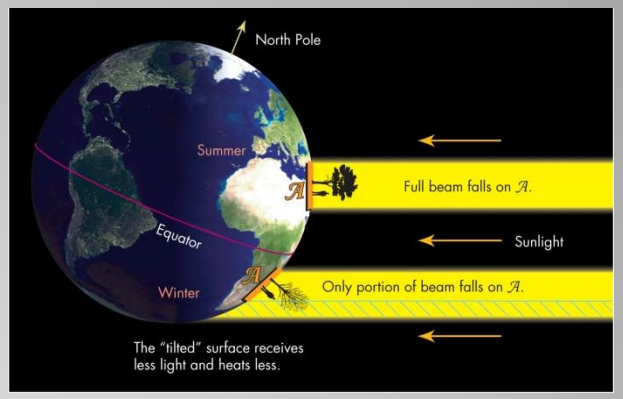
Introduction

- If the surface of Earth gets sunlight at a direct 90°, that will produce the most heat
- If the surface of Earth gets sunlight at anything less than 90°, then that will produce less heat
- 90° of sunlight = summer season
- >90° of sunlight = winter season



2. The Seasons

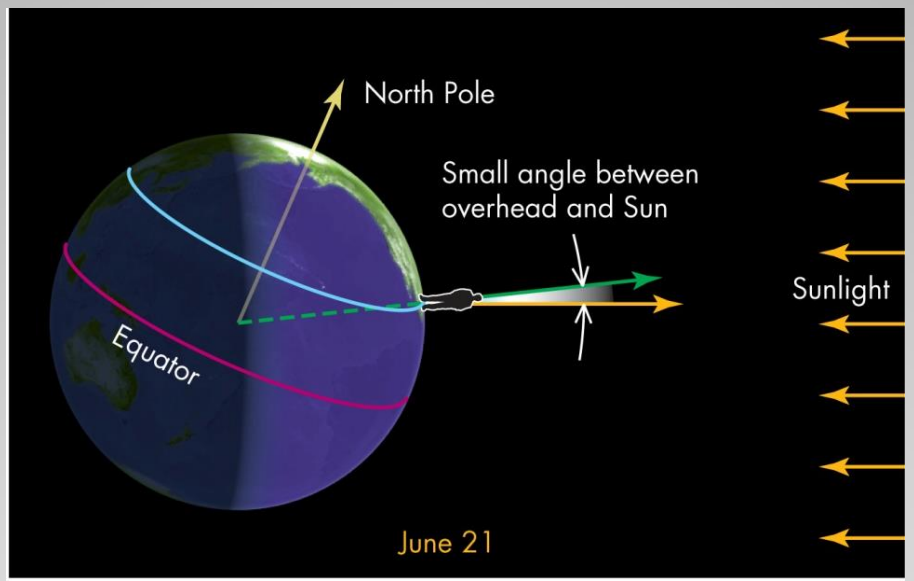
Introduction

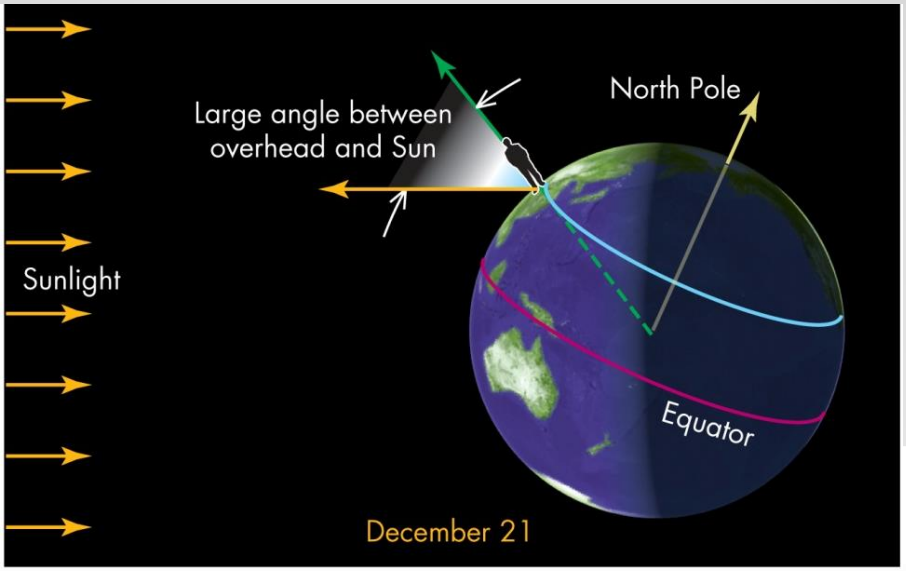


- Northern Hemisphere:
  - June – summer (90° of sunlight)
  - September – fall (> 90° of sunlight)
  - December – winter (>> 90° of sunlight)
  - March – spring (> 90° of sunlight)
- Southern Hemisphere: opposite of the north
- Equator:
  - June – mild (> 90° of sunlight)
  - September – hot! (90° of sunlight)
  - December – mild (> 90° of sunlight)
  - March – hot! (90° of sunlight)

2. The Seasons

Introduction

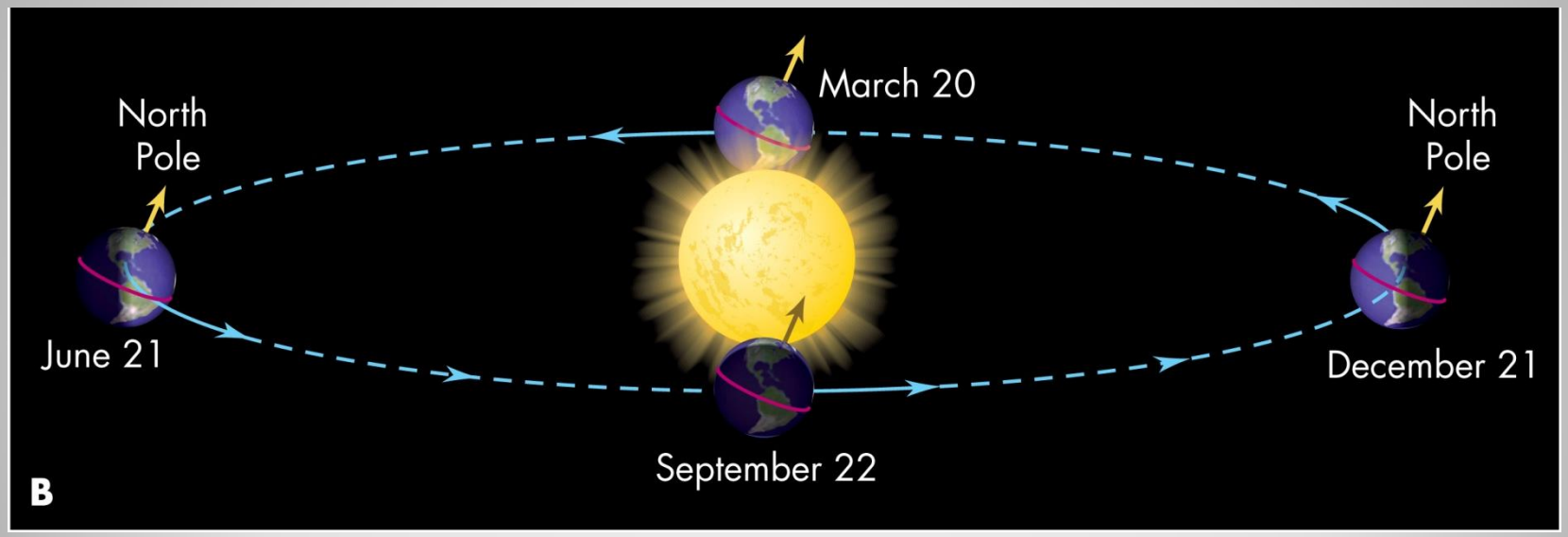




2. The Seasons

Introduction

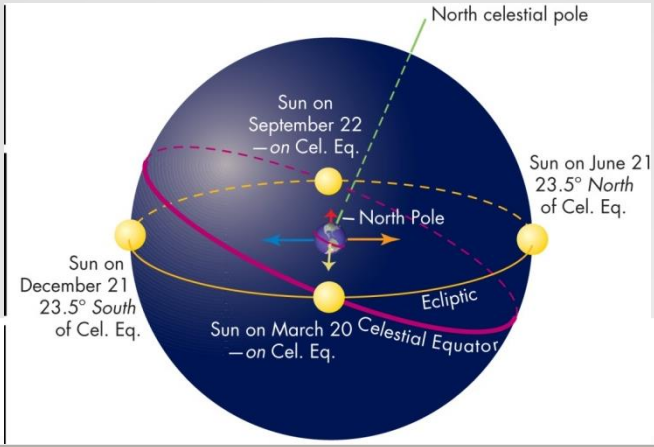
- Irony: at Earth's furthest point from the Sun, it's summer in the northern hemisphere, at the closest it's winter
- The seasons are distinctly caused by Earth's rotation axis



2. The Seasons

Solstices, Equinoxes, and Ecliptic's Tilt

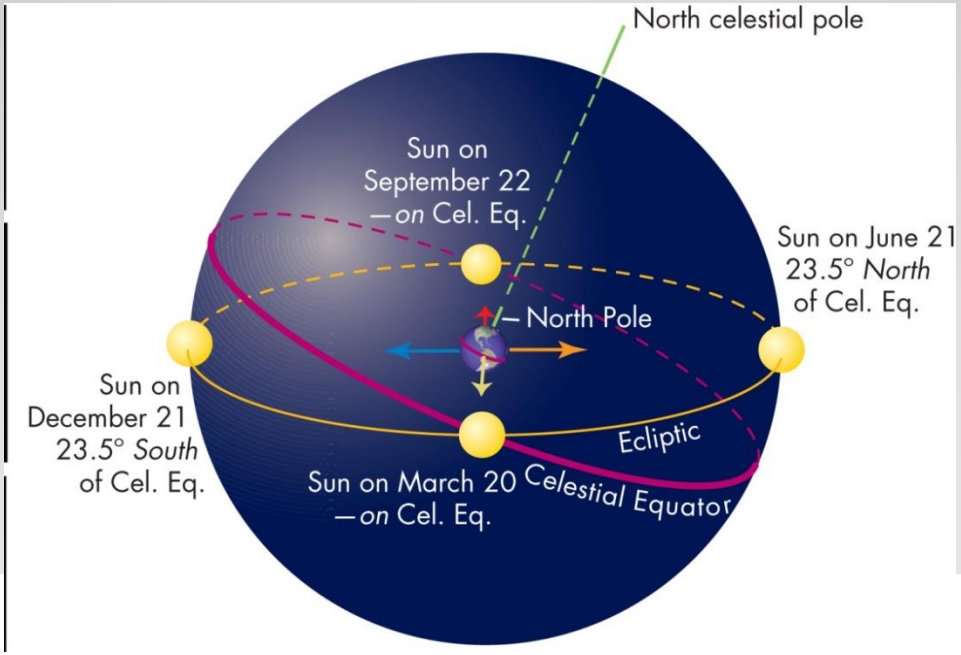
- Back to Earth…
  - Remember that from our prospective, every way we travel seems backwards in the sky
  - The Sun's path is included in that, too!
- The rotation axis is also responsible for the Sun's pathway in our view of the sky throughout the day
- It is tilted in respect to the celestial equator



2. The Seasons

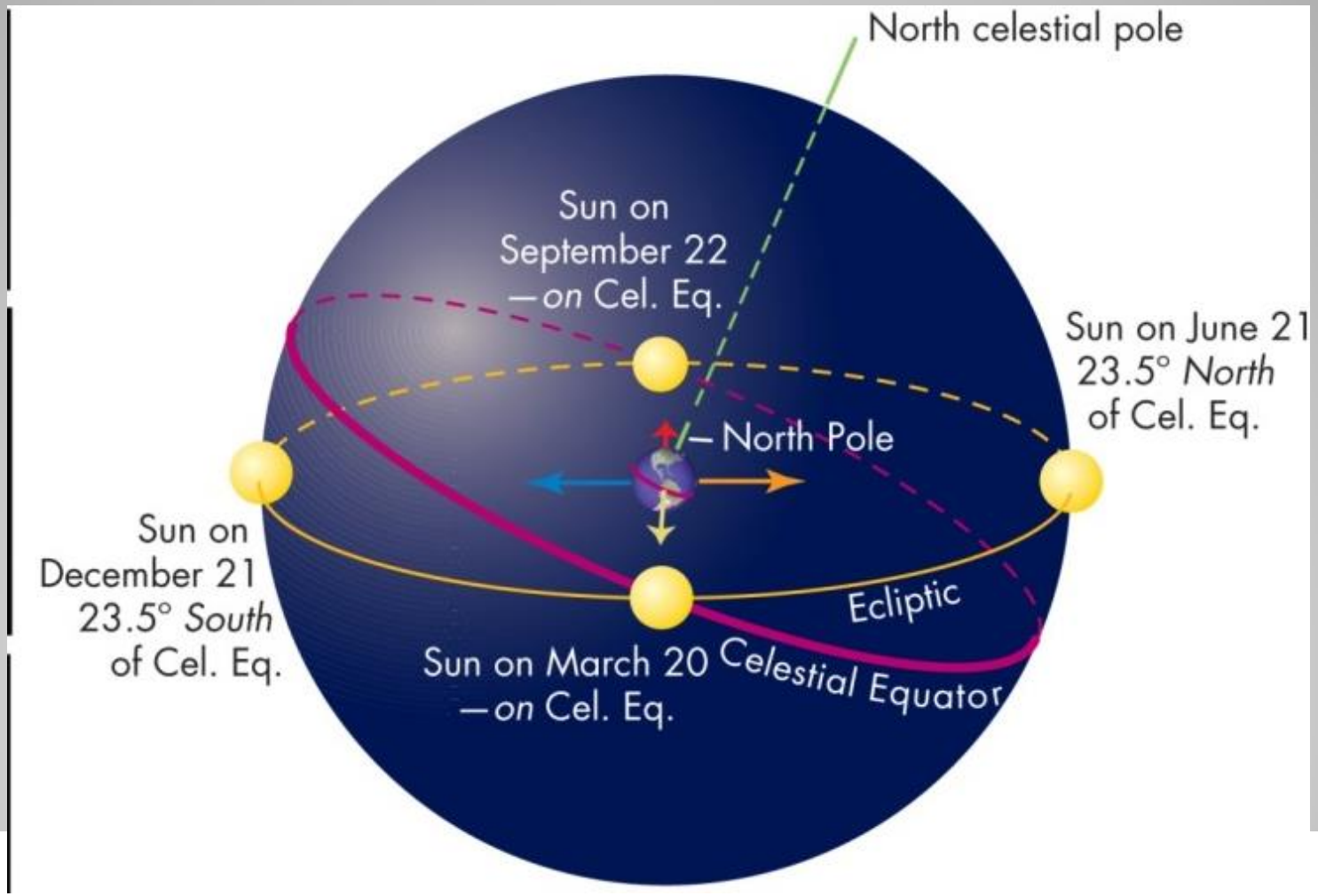
Solstices, Equinoxes, and Ecliptic's Tilt

- March 20th and September 22nd: The Sun directly hits the equator
  - This means the Sun would follow the celestial equator exactly
- In one year, the Sun will cross the celestial equator in the sky twice



2. The Seasons

Solstices, Equinoxes, and Ecliptic's Tilt



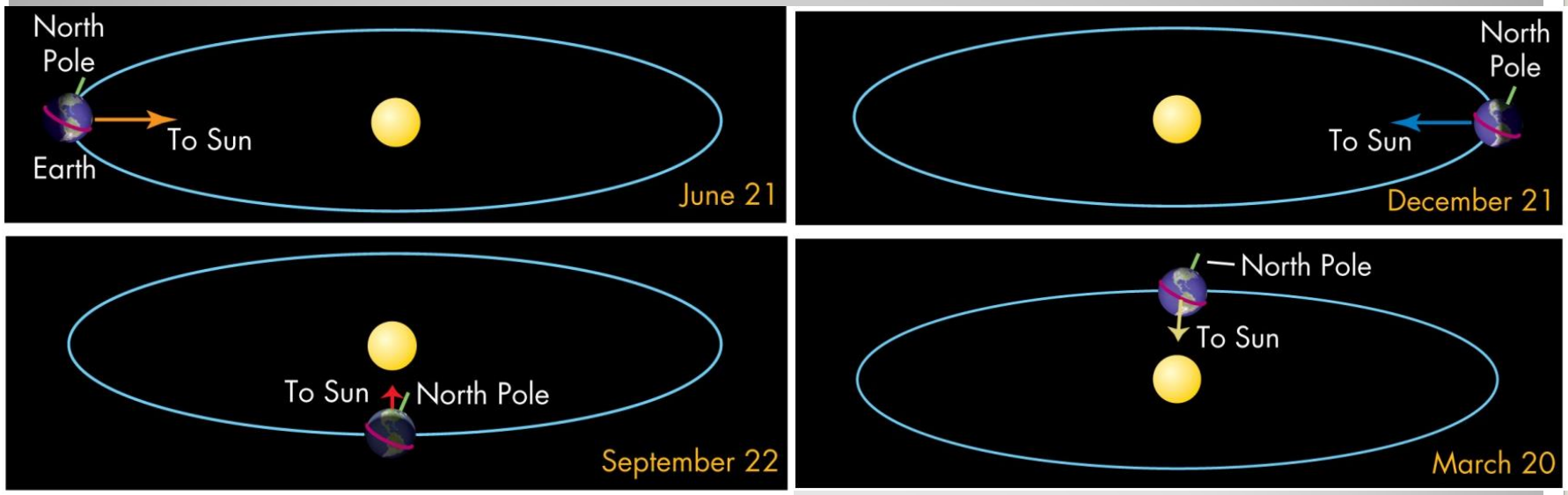
2. The Seasons

Solstices, Equinoxes, and Ecliptic's Tilt

- Equinox – the time of year when the Sun appears to cross the celestial equator
  - The number of daylight and nighttime hours are even
- Two of them:
  - Vernal Equinox – the start of spring (March 20th)
  - Autumnal Equinox – the start of fall (September 22nd)
- Solstice – the time of year when the Sun is at its greatest distance north and greatest distance south on the Earth
- Two of them:
  - Winter Solstice – the start of winter (December 21st)
  - Summer Solstice – the start of summer (June 21st)

2. The Seasons

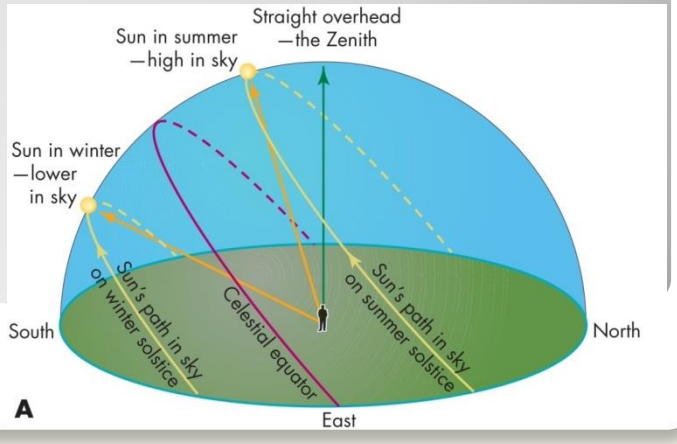
Solstices, Equinoxes, and Ecliptic's Tilt



2. The Seasons

Tracking the Sun's Changing Position

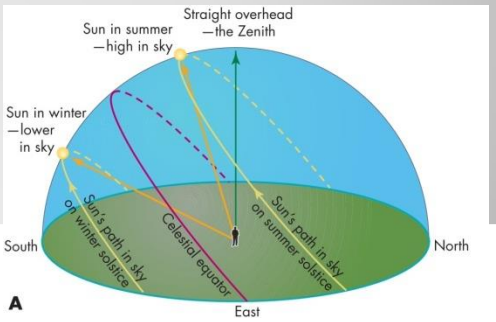
- With the visual of the sky being opposite of reality, the pathway and positions change, but they can be timed and tracked
- The Sun will be higher in the sky at noon on a summer day than it would be at noon on a winter day due to its distance from the celestial equator
  - This is just like the light angle on the planet



2. The Seasons

Tracking the Sun's Changing Position

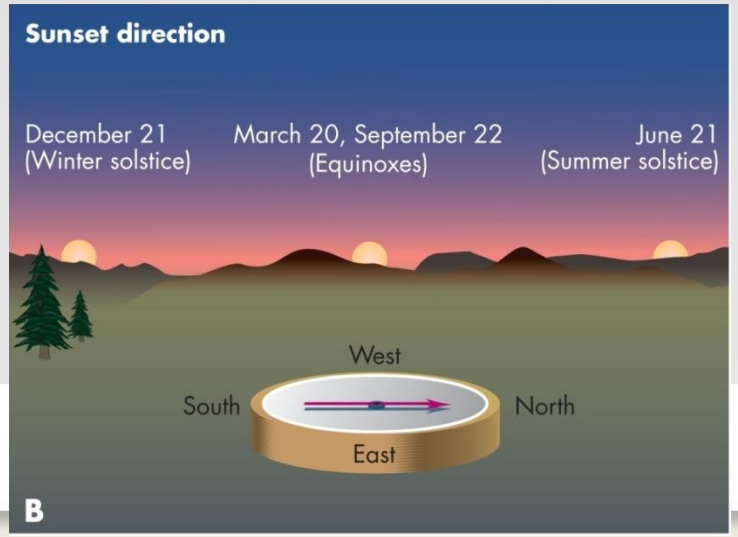
- On June 21st at 40° latitude: the noon Sun is about 73.5° above the horizon, about 16.5° from the Zenith
- On December 21st at 40° latitude: the noon Sun is about 26.5° above the horizon
- This causes the direction in which the Sun rises and sets to change!
  - It won't always be true East and West directions for the rising and setting (that will adjust with the changing position)



2. The Seasons

Tracking the Sun's Changing Position

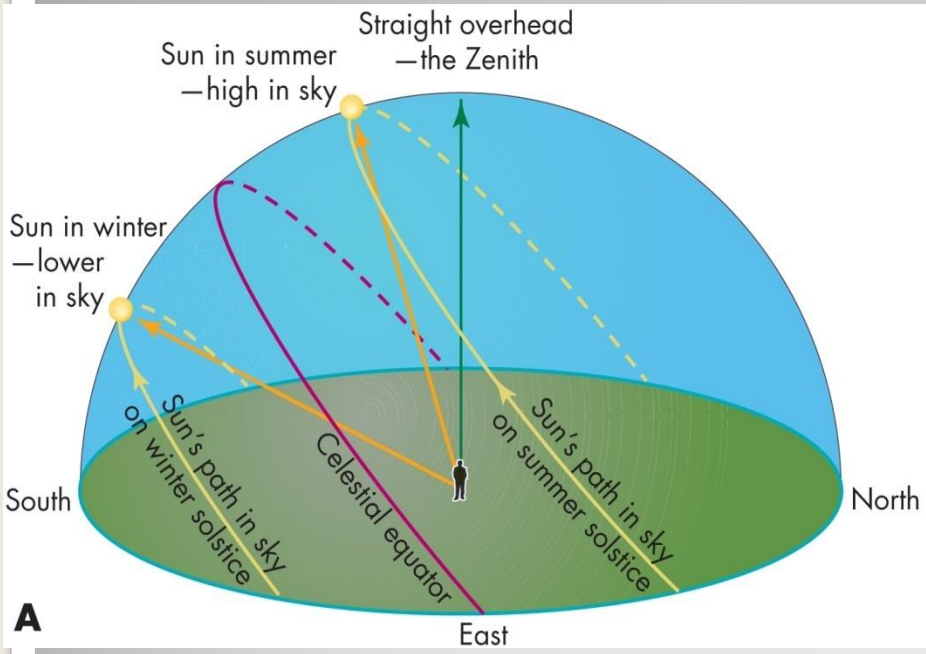
- On June 21st at 40° latitude: the Sun will rise in the northeastern direction and set in the northwestern direction
- On December 21st at 40° latitude: the Sun will rise in the southeastern direction and set in the northwestern direction
- Only during the equinoxes will it rise and set in exactly the east and west directions (that's where the celestial equator sits)

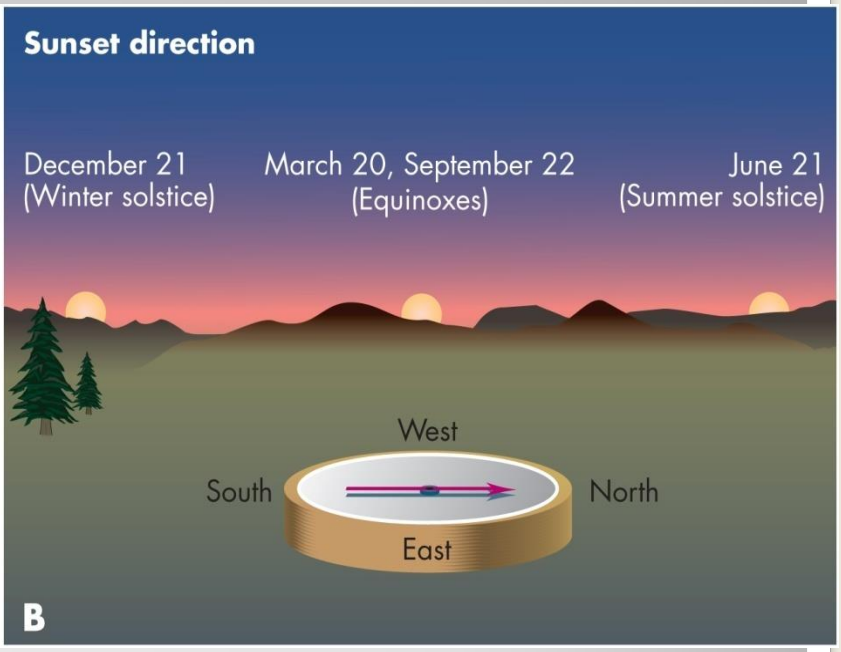


2. The Seasons

Tracking the Sun's Changing Position

- Let's compare side-by-side





2. The Seasons

Tracking the Sun's Changing Position

- Tracking the Sun is very latitude dependent!
  - Just like everything else…
- Many monuments and other buildings were constructed to help track the Sun, Moon, and other bodies as they traveled the sky throughout the year
- Prime example: Stonehenge (Amesbury, United Kingdom)