We can recognize solstices and equinoxes by Sun’s path across sky:

- **Summer solstice:** Highest path, rise and set at most extreme north of due east.
- **Winter solstice:** Lowest path, rise and set at most extreme south of due east.
- **Equinoxes:** Sun rises precisely due east and sets precisely due west.

If you are located in the continental U.S. on the first day of October, how will the position of the Sun at noon be different two weeks later?

A. It will have moved toward the north.
B. It will have moved to a position higher in the sky.
C. It will stay in the same position.
D. It will have moved to a position closer to the horizon.
E. It will have moved toward the west.

Under which of the following circumstances will a vertical flagpole not cast a shadow as seen from the continental United States?

A. every day at noon
B. every day at the time when the sun is highest in the sky
C. when the sun is highest in the sky on the summer solstice
D. when the sun is highest in the sky on the winter solstice
E. none of the above
For an observer in the continental U.S., which of the three shadow plots, shown at right, correctly depicts the Sun’s motion for one day?

A. Shadow plot A  
B. Shadow plot B  
C. Shadow plot C  
D. More than one of the plots are possible, on different days of the year.  
E. None of the plots are possible.

What causes the seasons?

• From the time we’re children, we learn that if the closer you are to a heat source, the warmer you will be  
• Can we apply that lesson to explaining the seasons?

These images of the Sun were taken 6 months apart. When was the image on the left taken?  
a) Summer (July)  
b) Winter (January)
Are seasons the same everywhere?
Consider the following conversation...

- **Niketta** (Moscow, Russia): “It is warmer in Moscow in July, so the Earth must be closer to the Sun at that time of year.”
- **Dundee** (Melbourne, Australia): “It is cooler in Melbourne in July, so the Earth must be farther from the Sun at that time of year.”
- **Mobutu** (Nairobi, Kenya): “We do not have seasons, so the Earth is always the same distance from the Sun, no matter the time of year.”

The seasons are **NOT** caused by variation in the distance between Earth and the Sun!

Actually, the Earth is **closest** to the Sun in *early January*

![Diagram showing Earth's orbit and Earth-Sun distances](image)

*But, it's only a small variation in the Earth-Sun distance - about 3% (5 million km)*

So what does cause the seasons?

![Diagram showing Earth's spin axis and seasons](image)

*Earth's spin axis is tilted 23.5° to its orbit*
Solstices and Equinoxes

Star Paths in Northern Hemisphere

- Stars rise at an angle to the horizon, up and south
- Some stars are circumpolar

How does the Sun move through the local sky?

- Sun’s path is like that of a star, except that its declination changes over the course of a year
- When north of the celestial equator
  - Rise north of east
  - Set north of west
  - Have long daily paths above the horizon
- When south of the celestial equator
  - Rise south of east
  - Set south of west
  - Have short daily paths above the horizon
As the Sun appears to move on the ecliptic, its daily path changes

**Summer solstice**
- Highest daily path
- Longest day/shortest night

**Equinoxes**
- Sun rises sets due east/west
- Day & night 12 hours

**Winter solstice**
- Lowest daily path
- Shortest day/longest night

How does the daily path of the Sun affect the weather?

(a) The Sun in summer
(b) The Sun in winter

Earth’s axis affects the directness of sunlight
The tilt of Earth’s axis of rotation produces longer (or shorter) hours of more (or less) direct sunlight.

In-class Activities: Seasons

- Work with a partner!
- Read the instructions and questions carefully.
- Discuss the concepts and your answers with one another. Take time to understand it now!!!!
- Come to a consensus answer you both agree on.
- If you get stuck or are not sure of your answer, ask another group.
- If you get really stuck or don’t understand what the question is asking, ask me.

Opposite seasons in the north and south.
Which of the locations identified with an “x” for each of the situations (A – E) would experience the coolest temperature over the course of one day?

Looking at the images below, which letter (a-e) best represents winter in the United States?

Note: this drawing is not to scale. In fact you could fit more than 11,000 Earths between the Sun and the Earth.
When do the seasons begin?

- The date at which each season begins depends on how it is defined.
- In the U.S., we usually use the Astronomical Seasons on our calendars.

<table>
<thead>
<tr>
<th>Season</th>
<th>Astronomical</th>
<th>Meteorological</th>
<th>Ancient Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>March 20</td>
<td>March 1</td>
<td>February 2</td>
</tr>
<tr>
<td>Summer</td>
<td>June 21</td>
<td>June 1</td>
<td>May 1</td>
</tr>
<tr>
<td>Autumn</td>
<td>September 22</td>
<td>September 1</td>
<td>August 1</td>
</tr>
<tr>
<td>Winter</td>
<td>December 21</td>
<td>December</td>
<td>November 1</td>
</tr>
</tbody>
</table>

When the Sun reaches the highest point on the ecliptic on about June 21st, its light will be most concentrated here in Bowling Green and the day will be the longest of the year. Why does the weather continue to get warmer after this date even though the days are shortening and the sunlight is getting less concentrated?

- a) We are still moving closer to the Sun.
- b) The Earth continues to tilt its top toward the Sun even after June 21st.
- c) Water, rock, and dirt take a long time to warm up or cool down.
Seasons in the Tropics and Polar Regions

Special Latitudes

- **Arctic Circle (66.5°N):** Sun never sets on summer solstice
- **Tropic of Cancer (23.5°N):** Sun directly overhead at noon on summer solstice

Special Latitudes

- **Antarctic Circle (66.5°S):** Sun never sets on winter solstice
- **Tropic of Capricorn (23.5°S):** Sun directly overhead at noon on winter solstice
Sun’s Path at Equator

- Sun rises straight up and sets straight down
- Sun is always high in the sky, so it’s always hot!
- The tropics typically have rainy and dry seasons

Sun’s Path at North Pole

- Sun never gets high in the sky, so it’s always cold
- When the Sun is below the celestial equator, very little, if any, daylight
- When the Sun is above the celestial equator, very little, if any, night

In the polar summer, the Sun is up 24 hours a day!

Sun’s Path at Tropic of Cancer

- Sun passes through zenith at noon on summer solstice
Sun’s Path at Arctic Circle

- Sun grazes horizon at midnight on summer solstice

Seasonal changes are more extreme at high latitudes

Path of the Sun on the summer solstice at the Arctic Circle

How does the orientation of Earth’s axis change with time?

- Although the axis seems fixed on human time scales, it actually precesses over about 26,000 years.
  - ⇒ Polaris won’t always be the North Star.
  - ⇒ Positions of equinoxes shift around orbit; e.g., spring equinox, once in Aries, is now in Pisces!