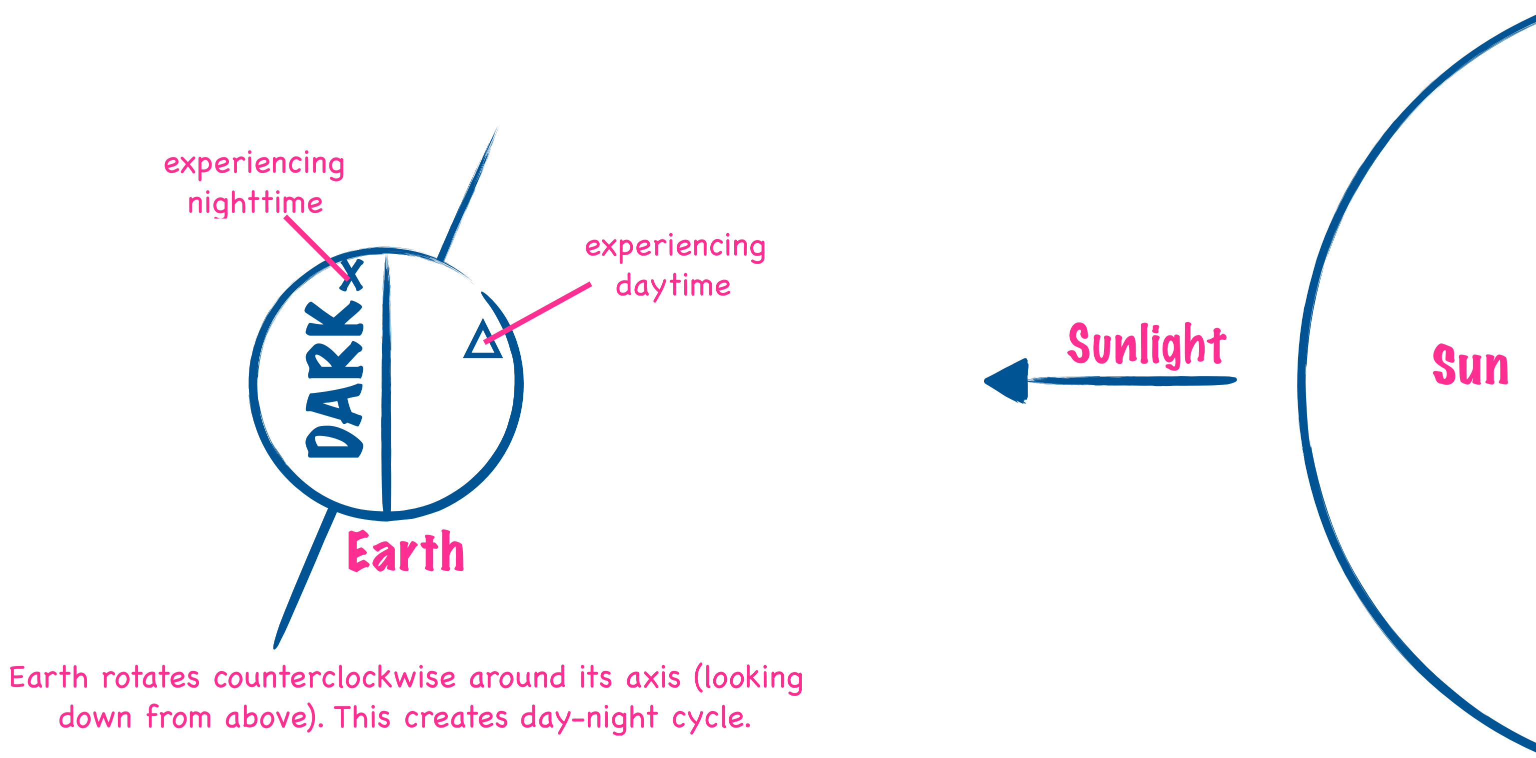
SEASONS
Session 1: Space-Based Perspectives

1. Draw a space-based diagram that shows why we experience day and night on Earth.



Make sure that you:

- ☐ **Include all objects** that you think are important to show your reasoning.
- ☐ **Label** the key parts of your diagram.
- ☐ **Shade** your diagram to show the unlit (nighttime) part.
- ☐ **Draw a triangle** on a location (a city) that is currently experiencing daytime.
- ☐ **Draw an X** on a location (a city) that is currently experiencing nighttime.
- ☐ Think about how a city like Boston experiences a day-night cycle. **Add arrows** to your diagram to show the movement of the Earth that explains **why** Boston experiences a day-night cycle. Think carefully about *which direction* things should move.

SEASONS
Session 2 - 3: Apparent Path of the Sun in the Sky

A. Make a prediction:

I think the Sun's apparent path in the sky each day is **different** throughout the year.
< the same / different >

If you think it is the same, explain *why* it is the same.
If you think it is different, describe *how* it is different.

It is different each day because Earth's fixed tilt of Earth changes the Earth-based orientation with the Sun as Earth moves around the orbital plane.

(But students won't be expected to know that yet, this is just to collect their initial ideas.)

B. Collect data for Boston:

Season and date	**Marker Color** (on SunTracker)	**Sun Angle at Midday** (in degrees)	**Length of Day** (in hours)
Winter (December 21)	**blue**	24°	9 hours
Spring (March 21)	**green**	48°	12 hours
Summer (June 21)	**red**	71°	15 hours
Fall (September 21)	**black**	48°	12 hours

C. Compare and analyze data for Boston:

1. Which season has the highest Sun angle at midday? Summer
2. Which season has the lowest Sun angle at midday? Winter
3. Which season has the longest day length? Summer
4. Which season has the shortest day length? Winter
5. Which seasons have the same Sun angle at midday / day length? Spring and Fall
6. Was the Sun ever directly overhead in Boston? Nope

D. Record your ideas:

How do you think the Sun's height in the sky and the length of day affect temperature on Earth?

1. Here are some ways I think the Sun's **height in the sky** affects temperature:

   Higher sun angles produce more concentrated light, resulting in more energy and higher temperature. (But students aren't expected to know that yet.)

2. Here are some ways I think the **length of day** affects temperature:

   More hours of daylight mean light and energy transmit to a location on Earth for a longer time, raising the temperature. (Again, hasn't been explained yet.)

SEASONS
Session 4: Sun Angle and Energy

Activity: Modeling Light from the Sun

In this activity you will use a flashlight and grid paper to model sunlight hitting the ground at different angles. You will explore how Sun angle affects the amount of ground illuminated by the Sun, which determines the amount of energy we receive from the Sun (and therefore, temperature).

A. Procedure:

1. Place the gridded paper on your desk. Place the bottom of the meter stick where the gridded paper tells you to.
2. Use a protractor (or half-SunTracker) to position the meter stick pointing straight up, at an angle of 90°. Turn off the room lights and turn on the flashlight. This represents a Sun angle of 90°.
3. Use a pencil to draw an outline around the area illuminated on the gridded paper. Label the outline with the current Sun angle.
4. Repeat step 2 at 60°, 30°, and 10°. Use your protractor (or half-SunTracker) to measure the angle. Keep the bottom of the meter stick on the bold line of the gridded paper for each trial.
5. Turn on the lights when everyone is finished.
6. For each Sun angle, count the number of squares illuminated by the flashlight, estimating if some squares are only partially lit. Record data in the table below.
7. For each Sun angle, determine the fraction of light striking each square and record it in the table. For example, if the flashlight illuminated 15 squares, then each square receives 1/15 of the light.

B. Collect data:

Complete this table with your group:

Sun Angle (in degrees)	**Number of Squares Illuminated** (area in cm^2)	**Fraction of Total Light Received by Each Square** (as a fraction)
90°	Different for each group	Different for each group
60°	Different for each group	Different for each group
30°	Different for each group	Different for each group
10°	Different for each group	Different for each group

C. Compare and analyze:

At which Sun angle was the largest area of ground illuminated? 10°

At which Sun angle was the smallest area of ground illuminated? 90°

At which Sun angle did each square of ground receive the most amount of light (and therefore, the most intense light)? 90°

When sunlight is more intense, the temperature will be (warmer / cooler). warmer

At which Sun angle did each square of ground receive the least amount of light (and therefore, the least intense light)? 10°

When sunlight is less intense, the temperature will be (warmer / cooler). colder

D. Record your ideas:

Based on **what we have learned so far**, explain ***why*** you think it is warmer in the summer than in the winter.

Try to connect what you have learned about:

(1) how the Sun appears to move in the sky during different seasons;
(2) how the Earth's axis affects the mid-day Sun angle; and
(3) how the Sun's angle in the sky affects the intensity of light we receive.

It is warmer in the summer because the hemisphere is tipped towards the Sun, which results in a higher sun angle. Higher sun angles produce more intense sunlight, and therefore more concentrated energy (and warmth).

Name: ______________________________

SEASONS
Session 5: Earth's Tilted Axis

1. Model a Year

Model Earth orbiting the Sun, using the Seasons sheet on your table as a guide.
Note: Be sure to always point your Earth's axis in the direction indicated by the instructor.

- ☐ Place your team's Seasons Sheet on the table. Match the orientation of the seasons on the sheet to the signs hung around the room. Place a ring on the Seasons sheet. Place your Sun on the ring.
- ☐ Each team member should stand around your table at one of the season positions marked on the sheet. Each team member should represent a different season.
- ☐ Summer team member:
  - ☐ Hold Earth on the side of the Sun that represents Summer. Orient the tilt of Earth's axis in the direction indicated by the instructor.
  - ☐ Holding the dowel that represents Earth's axis, move Earth through your season to model how Earth orbits around the Sun during Summer.
  - ☐ Pass Earth to the Fall team member, always keeping the axis pointed in the correct direction.
- ☐ Fall, Winter, and Spring team members:
  - ☐ Take turns repeating the steps above during your season. Fall team member will model Earth's orbit during Fall, then pass Earth to Winter team member, and so on.
  - ☐ Make to complete a full Year by passing Earth through every season and back to Summer.

2. Model a Day at Different Times of Year

- ☐ Summer team member: Rotate Earth at the Summer position, so your Lego person experiences both night and day. All teammates should make sure that the axis orientation remains correct.
- ☐ Fall team member: Rotate Earth at the Fall position, so your Lego person experiences both night and day. All teammates should make sure that the axis orientation remains correct.
- ☐ Pass and repeat for the other two seasons.

3. Observe from the Model

When Earth experiences **Summer** in the Northern Hemisphere:

1. The Northern Axis is tilted __towards__ (< towards / away from >) the Sun.
2. The Southern Axis is tilted __away from__ (< towards / away from >) the Sun.
3. To see the Sun at midday, Lego person must look __up__ (< up / ahead >), __high__ (< high / low >) in the sky.

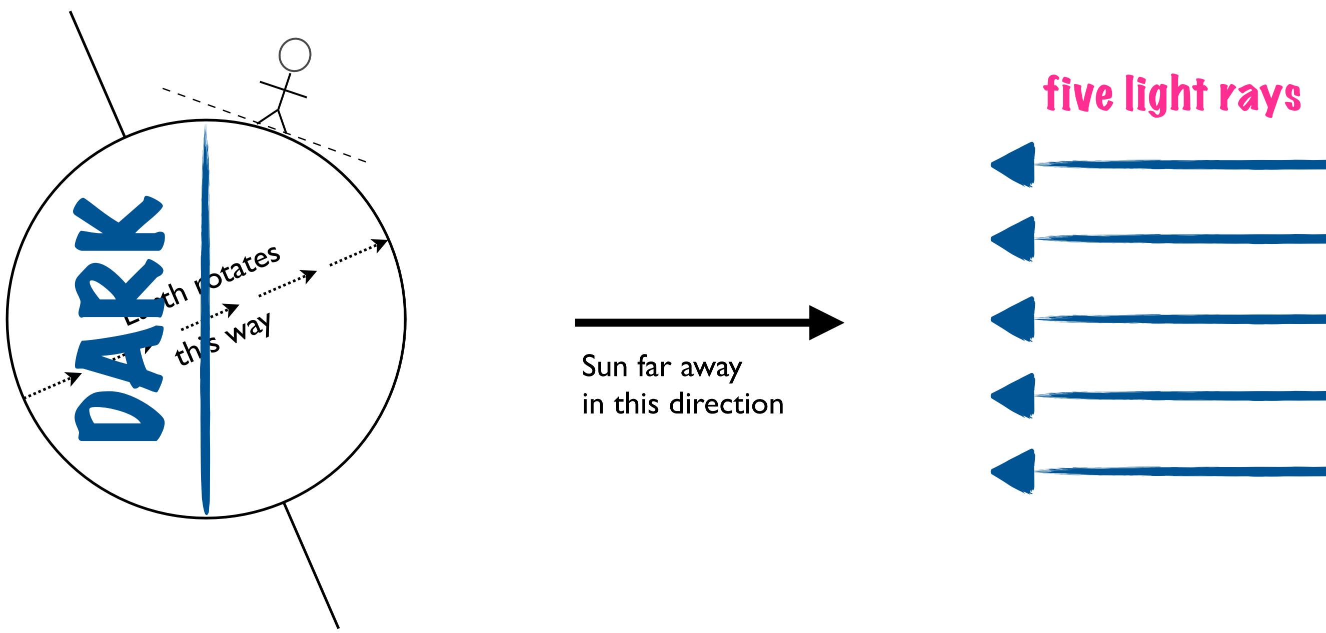
When Earth experiences **Winter** in the Northern Hemisphere:

1. The Northern Axis is tilted __away from__ (< towards / away from >) the Sun.
2. The Southern Axis is tilted __towards__ (< towards / away from >) the Sun.
3. To see the Sun at midday, Lego person must look __ahead__ (< up / ahead >), __low__ (< high / low >) in the sky.

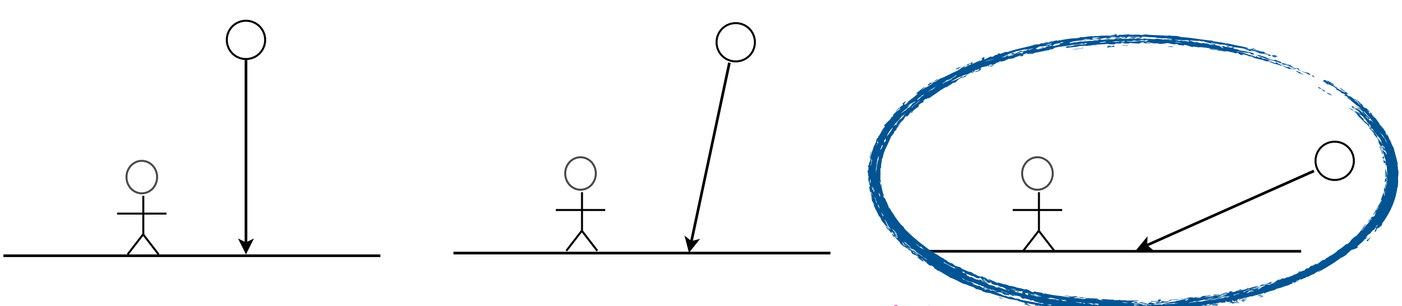
SEASONS
Session 6: Tilted Axis and Sun Angle

A. Interpret This Diagram:

Diagram **NOT** to scale.

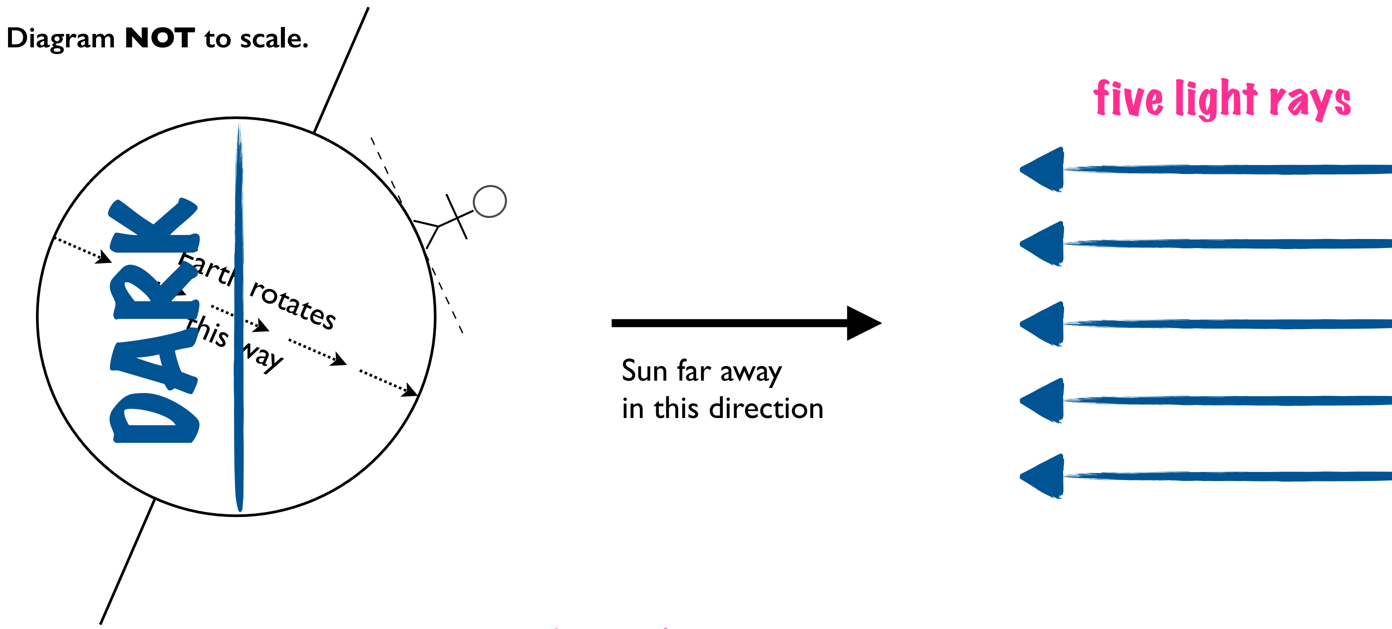


1. The Northern Hemisphere is tilted ___away from___ the Sun.
   < towards / away from >
2. Sketch in **five light rays** from the Sun, to show how you think sunlight reaches Earth.
3. Shade the diagram to show which part of Earth is **dark**.
4. What time of day do you think it is for the stick person above? ___midday___
   < sunrise / midday / sunset / midnight >
5. Circle which of the three figures below you think best represents the angle of sunlight hitting the person's ground at the moment shown above. The angle of sunlight is the same as the Sun Angle.

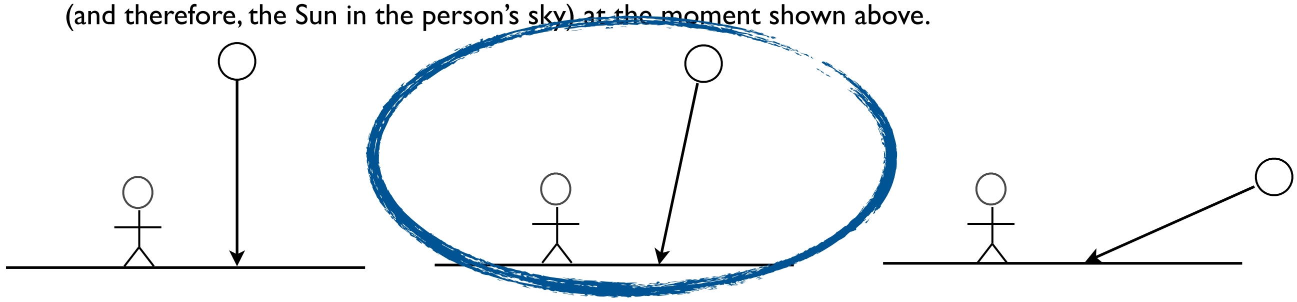


6. What season do you think it is for the stick person? ___winter___
   < summer / winter >

B. Interpret this diagram:



1. The Northern Hemisphere is tilted ___towards___ the Sun.
   < towards / away from >
2. Sketch in **five light rays** from the Sun, to show how you think sunlight reaches Earth.
3. Shade the diagram to show which part of Earth is **dark**.
4. What time of day do you think it is for the stick person above? ___midday___
   < sunrise / midday / sunset / midnight >
5. Circle the figure that you think best represents the angle of sunlight hitting the person's ground (and therefore, the Sun in the person's sky) at the moment shown above.



6. What season do you think it is for the person? ___summer___
   < summer / winter >

C. Compare:

When the Northern Hemisphere is tilted **towards** the Sun, the Sun is ___high___ in the sky at midday. This is ___summer___ .
< high / low >
< summer / winter >

When the Northern Hemisphere is tilted **away from** the Sun, the Sun is ___low___ in the sky at midday. This is ___winter___ .
< high / low >
< summer / winter >

Name: ______________________________

SEASONS
Session 6: Bonus Questions

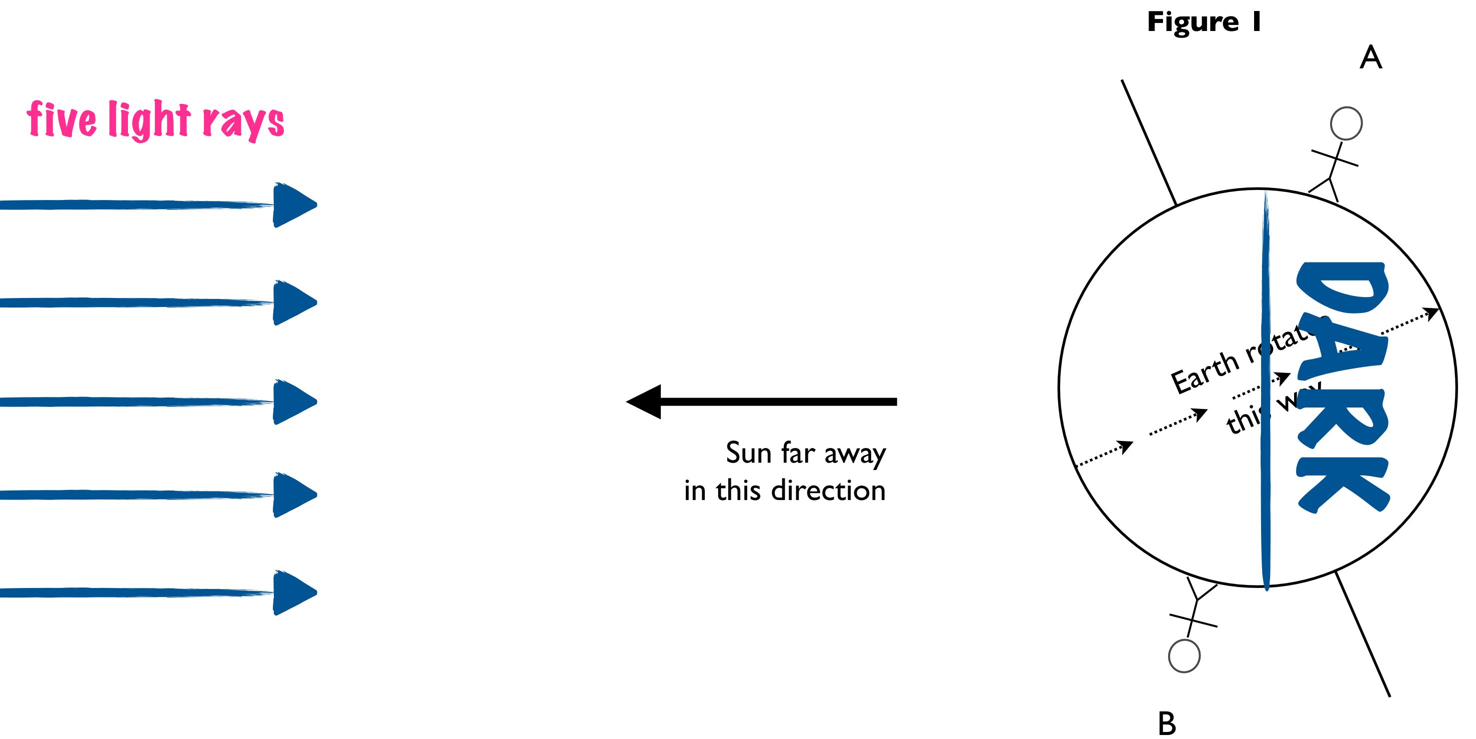


Diagram **NOT** to scale.

1. Sketch in **five light rays** from the Sun.
2. Shade the **dark part** of Earth.
3. What time of day is it for Person A? midnight
4. What season is it for Person A? summer

   Explain why you think so:

   It is summer for Person A because they are standing in the Northern Hemisphere, and this Hemisphere is currently tilted toward the Sun

5. What time of day is it for Person B? midday
6. What season is it for Person B? winter

   Explain why you think so:

   It is winter for Person B because they are standing in the Southern Hemisphere, and this Hemisphere is currently tilted away from the Sun

Figure 2

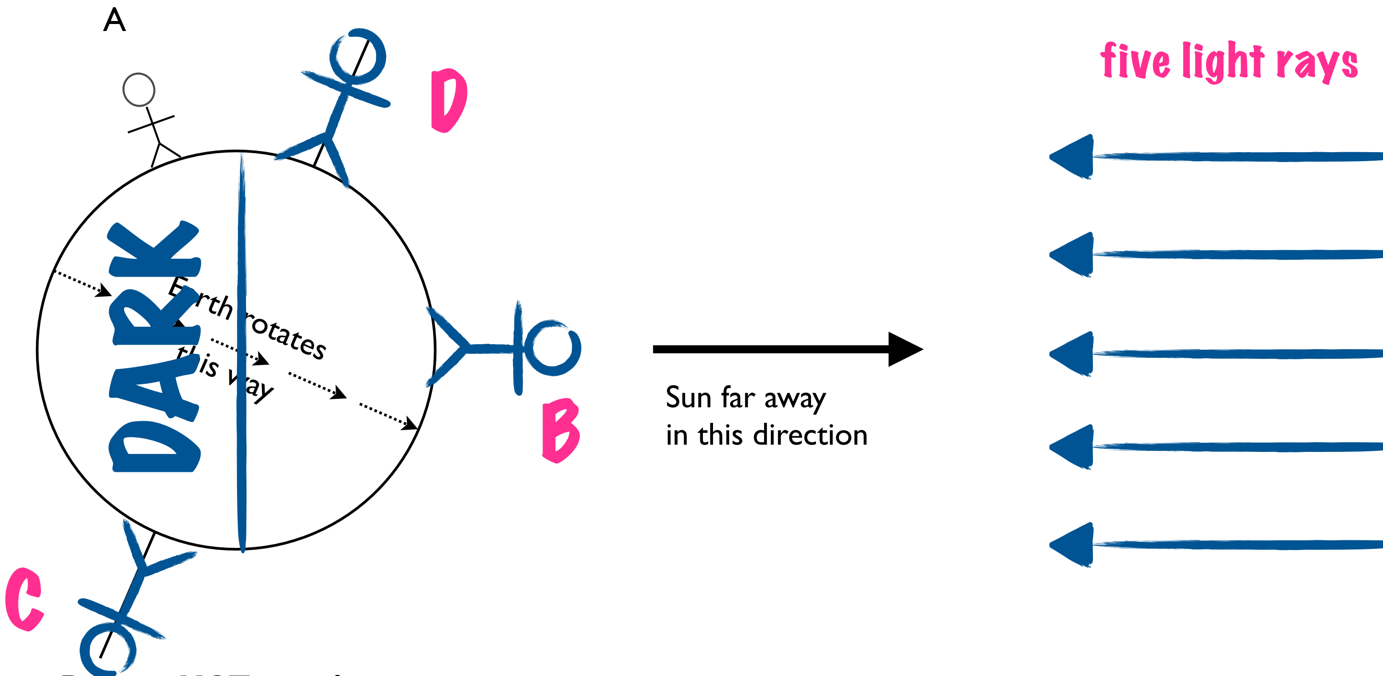


Diagram **NOT** to scale.

1. Sketch in **five light rays** from the Sun.
2. Shade the **dark part** of Earth.
3. **True or False?** Figure 1 and Figure 2 show the same time of day and the same season for Person A. true
4. Sketch in a person for whom the Sun is **directly overhead** on this day. Label this Person B.
5. Sketch in a person who will **never see the Sun** on this day. Label this Person C.
6. Sketch in a person who will **never experience darkness** on this day. Label this Person D.

SEASONS
Session 7: Tilt and Day Length

1. Collect Data: Total hours of daylight around the world

on June 21

A. The Northern Hemisphere is tilted toward the Sun.
< toward / away from >

B. A place that spends this **entire day in darkness** (never sees the Sun) is McMurdo Station.

This place is in the Southern Hemisphere, close to the South Pole.
< Northern / Southern > < North Pole / South Pole / Equator >

C. A place that spends less time in daylight than darkness is Puerto Montt.

This place is in the Southern Hemisphere, which is tilted away from the Sun.
< Northern / Southern > < toward / away from >

on December 21

D. The Northern Hemisphere is tilted away from the Sun.
< toward / away from >

E. A place that spends more time in daylight than darkness is Puerto Montt.

This place is in the Southern Hemisphere, which is tilted toward the Sun.
< Northern / Southern > < toward / away from >

F. A place that spends the same amount of time in daylight as darkness is Quito.

This place is located near the Equator.
< North Pole / South Pole / Equator >

G. A place that spends the **entire day in daylight** (never sees the Sun set) is McMurdo Station.

Sept. 21

H. Barrow, Alaska spends the same amount time in daylight than darkness.
< more / the same amount of / less >

I. Puerto Montt, Chile spends the same amount time in daylight than darkness.
< more / the same amount of / less >

2. Compare

A. When the Northern Hemisphere is tilted toward the Sun, the Southern Hemisphere is tilted ___away from___ the Sun.
< toward / away from >

B. Cities in the hemisphere tilted **toward the Sun** have ___more___ hours of daylight than darkness.
< more / the same amount of / fewer >

C. Cities in the hemisphere tilted **away from the Sun** have ___fewer___ hours of daylight than darkness.
< more / the same amount of / fewer >

D. Some places on Earth have roughly equal amounts of daylight and darkness every day of the year. These places are close to the ___Equator___ .
< Equator / Poles >

E. There are places on Earth where on certain days of the year, the Sun never rises or never sets for an entire day. These places are close to the ___Poles___ .
< Equator / Poles >

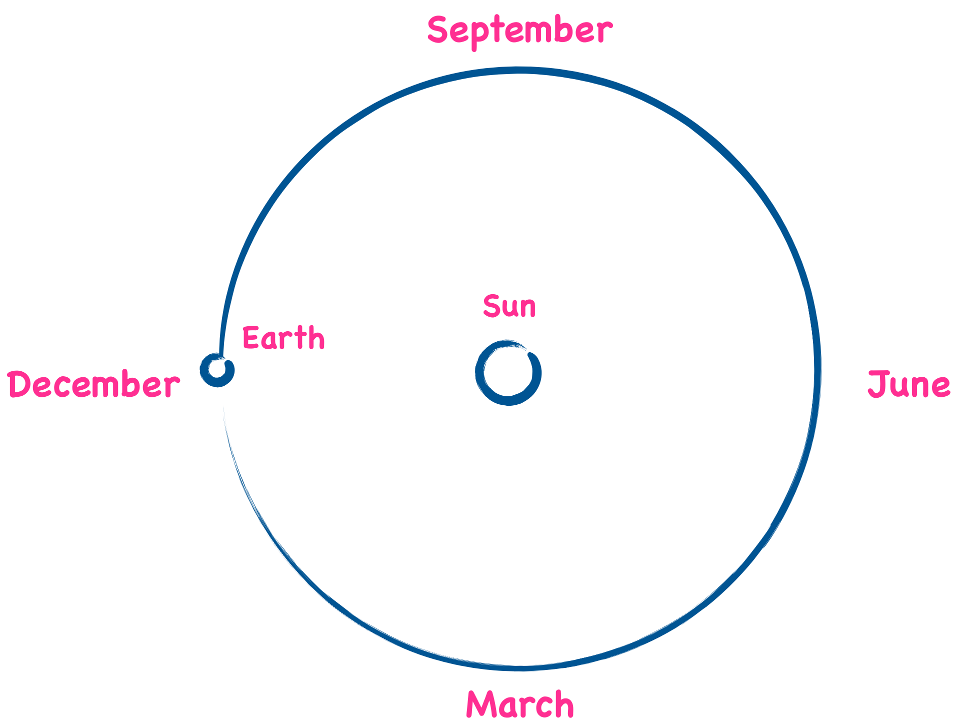
F. On September 21 and March 21, the total hours of daylight are ___the same as___ the total hours of darkness everywhere on Earth.
< more than / the same as / fewer than >

These dates are known as the ___Equinoxes___ .

SEASONS
Session 8: Earth's Orbit

1. What shape is Earth's orbit?

A. Draw a diagram of Earth's orbit around the Sun from an **overhead** perspective.
B. Label all the key parts of your diagram.
C. Label where you think Earth is when it's September, December, March, and June.



2. Distance from Earth to the Sun

Predict: In what month (if ever) do you think Earth is closest to the Sun? January

Date (and season in Boston)	**Collect Data** distance from Earth to the Sun (in kilometers)
December 21 Boston winter	147 million kilometers
March 21 Boston spring	149 million kilometers
June 21 Boston summer	151 million kilometers
September 21 Boston fall	149 million kilometers

3. Compare and analyze

Use the data in your table on the previous page to answer these questions:

Earth is closest to the Sun when it is ____winter____ in the Northern Hemisphere.
< fall / winter / spring / summer >

Earth is farthest from the Sun when it is ____summer____ in the Northern Hemisphere.
< fall / winter / spring / summer >

4. Reflect

A common belief for why we experience Seasons is that Earth is closer to the Sun in the summer, and farther away in the winter.

Do you agree or disagree with this? ____disagree____
< agree / disagree >

Explain your reasoning. If you disagree, please explain **why** you think we have seasons.

Earth is further away from the Sun when it is summer in the Northern Hemisphere, so this doesn't make sense. We have seasons because the fixed tilt of the Earth results in more intense sunlight and longer days during certain periods of the orbit around the Sun.

5. Recap

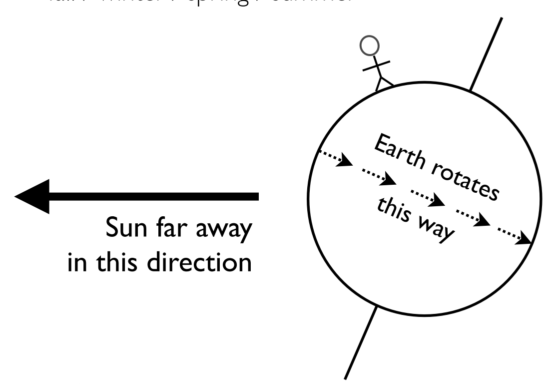
i. What season is it for the person in the diagram to the right? ____winter____
< fall / winter / spring / summer >

ii. The person in this diagram will experience *(circle one)*:

a. A longer day and shorter night

b. Roughly an equal day and night

c. A longer night and shorter day



iii. Sketch a side-view of Earth and the Sun when the Southern Hemisphere is experiencing winter.