A Content Secondary Science Newsletter from the Southern Nevada Regional Professional Development Program

Science Dissected

The Earth's Seasons

Model-Evidence Link Diagram (MEL)

What causes the Earth to have seasons? It is true that the Earth travels around the Sun in an elliptical orbit causing the Earth to be closer to the Sun at some times and farther away at others. Many people hold on to the common misconception that this is what causes the seasons, but it does not. The Earth has a tilted axis that causes an unequal heating of the planet. One hemisphere will be experiencing more direct sunlight and warmer temperatures during summer, while at the same time, the other hemisphere is experiencing less direct sunlight and cooler temperatures during winter. This issue of Science Dissected provides an instructional resource for teachers to present students with the opportunity to examine several pieces of evidence compiled about Earth's seasons and critically evaluate two competing models.

Model A: The seasons are caused by Earth's distance from the Sun.

Model B: The seasons are caused by Earth's tilt.

Evidence #1: Kepler's laws of planetary motion state that the Earth follows an elliptical path around the sun therefore the Earth is sometimes closer to the Sun and sometimes farther away.

Evidence #2: The Earth's axis is tilted causing unequal heating of the Earth. One hemisphere will be warmer with more direct sunlight while at the same time; the other hemisphere will be cooler due to less direct sunlight.

Evidence #3: The changing location of the Earth in its orbit around the sun results in the different seasons. The northern hemisphere will have summer, while the southern hemisphere has winter.

Additional Evidence Ideas…
Include a laboratory experiment which requires the students to make a model or act out the locations, distances, and angles of tilt for the Earth and Sun at different times of the year.

The following is a suggestion for using this MEL with students:

1. Hand out the Seasons Model Evidence Link Diagram (page 1). Instruct students to read the directions, descriptions of Model A and Model B, and the three evidence texts presented.
2. Handout the three evidence text pages (pages 3-9).
3. Instruct students to carefully review the Evidence #1 text page (page 3), then construct two lines from Evidence #1; one to Model A and one to Model B. Remind students that the shape of the arrow they draw indicates their plausibility judgment (potential truthfulness) connection to the model.
4. Repeat for Evidence #2-3 (pages 4-9). This may take more than one class period.
5. Handout page 2 for the students to critically evaluate their links and construct understanding.

Once students have completed page 2, they can then engage in collaborative argumentation as they compare their links and explanations with that of their peers. Students should be given the opportunity to revise the link weighting during the collaborative argumentation exercise. If time permits, have students reflect on their understanding of the seasons and create questions that they might explore in the future.

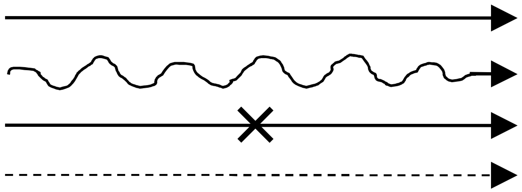
Archived Issues of Science Dissected, http://www.rpdp.net/link.news.php?type=sciencedis. Instructional Resource resulting from Plausibility, It's All About Connecting the Models Workshop co-sponsored by CPDD and SNRPDP Science March 6, 2012

Written by: Tracy Fries

Name:____ ____________________ **Period:**________________

Directions: draw two arrows from each evidence box. One to each model. You will draw a total of 6 arrows.

Key:



The evidence **supports** the model

The evidence **STRONGLY supports** the model

The evidence **contradicts** the model (shows its wrong)

The evidence has **nothing to do with** the model

Standard: E.8.A.1

Evidence #1
Kepler's laws of planetary motion state that the Earth follows an elliptical path around the sun therefore the Earth is sometimes closer to the Sun and sometimes farther away.

Model A
The seasons are caused by the Earth's distance from the Sun.

Model B
The seasons are caused by the Earth's tilt.

Evidence #2
The Earth's axis is tilted causing unequal heating of the Earth. One hemisphere will be warmer with more direct sunlight while at the same time; the other hemisphere will be cooler due to less direct sunlight.

Evidence #3
The changing location of the Earth in its revolution around the sun results in the different seasons. The northern hemisphere will have summer, while the southern hemisphere has winter.

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate descriptor (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write the letter of the model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

4. Circle the plausibility of each model. [Make two circles. One for each model.]

	Greatly implausible (or even impossible)									Highly Plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

5. Circle the model which you think is correct. [Only circle one choice below.]

Very certain that Model A is correct	Somewhat certain that Model A is correct	Uncertain if Model A or B is correct	Somewhat certain that Model B is correct	Very certain that Model B is correct

EVIDENCE #1: Kepler's laws of planetary motion state that the Earth follows an elliptical path around the sun therefore the Earth is sometimes closer to the Sun and sometimes farther away.

Original source: http://www.studyphysics.ca/newnotes/20/unit02_circulargravitation/chp08_space/lesson34.htm

Kepler's Laws of Planetary Motion

Kepler's First Law

Kepler's First Law went against the major assumption that scientists of the time had about orbits… in fact it is probably against the image of orbits that you have!

- If I asked you to describe or draw a sketch of the Earth's orbit around the sun, how would you draw it? Think about it in your head.
- You'd probably stick the sun in the center and draw a circle around it to show the path the Earth takes.
- In fact, this is totally wrong, as **Kepler's First Law** states…

"The path of any object in an orbit follows the shape of an ellipse,
with the orbited body at one of the foci."

So what does all that mean?

- An ellipse is shaped like a circle that someone has sat on. It's squished in the middle, like an oval.
- Foci (the plural form of the word focus) are two points inside the ellipse.
- If you were to push stick pins into the foci and put a loop of string around them, you could draw an ellipse.
- This means we have a shape that looks like this…

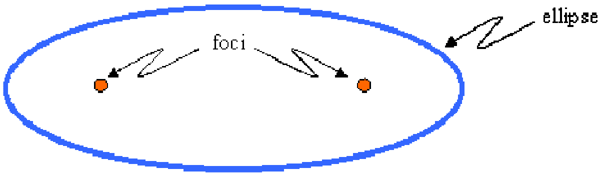


Figure #1

Remember that the object being orbited sits at one focus, and the other object follows the path of the ellipse.

- The correct sketch of the **Earth** orbiting the **Sun** should look like this…

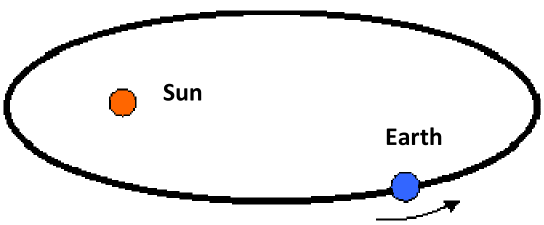


Figure #2

- This means that sometimes the **Earth** is closer to the **Sun**, and sometimes further away.
- This is not the reason for summer and winter!
- The seasons on Earth are created by Earth's tilt on its axis.

The diagrams drawn here are exaggerated quite a bit to show the elliptical shape and focus clearly.

- The true orbit of planets isn't this much flattened out.
- This elliptical shape does not apply to just planets orbiting the sun. It works for any object orbiting any other object.
- If you measured the orbit of the Moon around the Earth, it would have an elliptical shape, and so would any satellite in orbit around the Earth.
- Since orbits around the Earth are quite small, their shapes are *almost* a circle.

Newton was able to show that his laws of gravitation gave the same results as Kepler's. In fact, Newton was able to take things farther with his strong math background to show that the shape of the orbits were conic sections.

Kepler's Second Law

Kepler's Second Law is based on the speed of the object as it orbits.

- In the Earth-Sun example shown in **Figure 2**, the Earth will travel faster and faster as it gets closer to the sun.
- As the Earth moves away from the sun, it will move slower and slower.
- It's almost like the Earth is being "slingshot" around the sun very quickly as it passes near it.

Kepler didn't talk about speed when he wrote out his **second law**. Instead, he looked at a mathematical detail that pops out because we are talking about ellipses.

"An imaginary line from the sun to the planet
sweeps out equal areas in equal times."

If we were to look at the area the Earth sweeps out in a 15 day period, first when close to the sun (**Figure 3**) and then when far away (**Figure 4**), we would get diagrams that look like this.

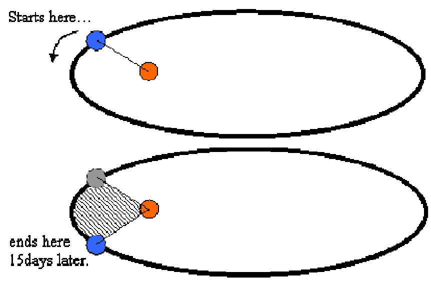


Figure #3

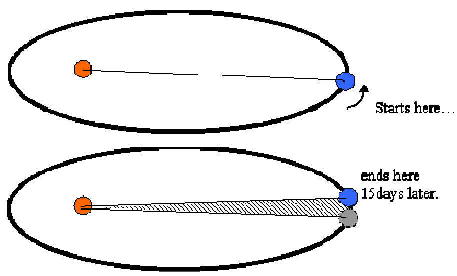


Figure #4

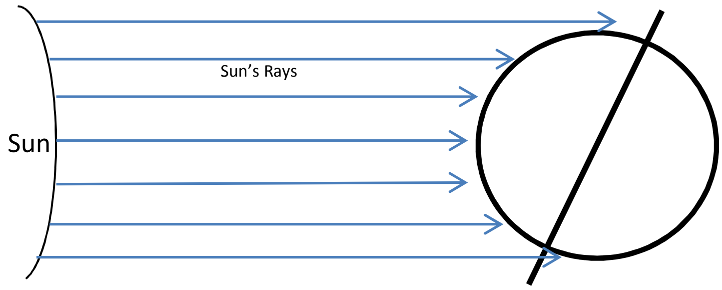
Notice how in **Figure 3** we have a stubby, fat, (basically) triangular area that was swept out by the line, but in **Figure 4** we have a tall, thin, (basically) triangular area swept out.

- If we calculate the **areas** that are shaded in as triangles, you would find that they are equal.
- This just shows that the planet is moving a lot faster when it is closer to the sun, since you can see that it traveled a greater distance along its orbit during that time.

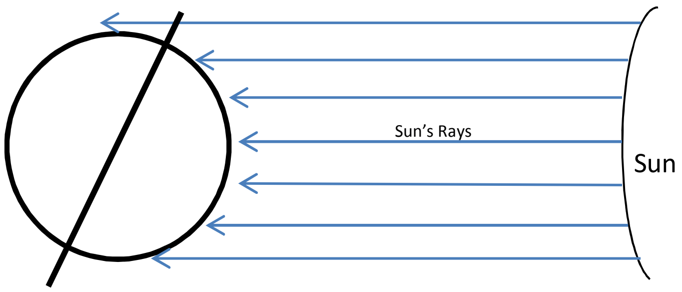
EVIDENCE #2: The Earth's axis is tilted causing unequal heating of the Earth. One hemisphere will be warmer with more direct sunlight while at the same time; the other hemisphere will be cooler due to less direct sunlight.

Original source: http://sciencenetlinks.com/science-news/science-updates/tilted-earth/

The Earth's Axis:
The Earth's axis is basically an imaginary stick going through the center of the earth, if we define the center as "the point around which it rotates." In other words, picture the earth spinning like a top, straight up and down. Now picture a stick going right through the center of the earth. If the earth weren't tilted, it would rotate like that as it revolved around the sun, and we wouldn't have seasons—only areas that were colder (near the poles) and warmer (near the Equator).
But the Earth's axis is tilted 23.5 degrees. This causes an unequal heating of the Earth.



Unequal Heating of the Earth:
The Sun is 93 million miles away from the Earth. The Sun is also 1.3 Million times larger than the Earth. Because the Sun is so big and so far away, the Sun's rays basically hit Earth parallel to one another. The diagram above shows the southern hemisphere getting more direct sunlight than the northern hemisphere. In this diagram, the southern hemisphere is pointing at the sun and therefore experiencing summer, the temperatures would be warmer and they would also be getting more hours of sunlight. In fact, right at the South Pole there would be 24 hours of daylight, the sun would never set. The upper part of the diagram shows the northern hemisphere pointing away from the sun and getting only indirect sunlight. The sunlight is hitting the northern hemisphere at an angle, which keeps the temperatures cooler. The northern hemisphere is experiencing winter and fewer hours of daylight. In this diagram, you can see that the North Pole would not receive any daylight at all. It would be dark all 24 hours of the day in the winter. Near the equator the sun shines more or less equally throughout the whole year. The Earth is actually closer to the sun during the Northern Hemisphere's winter, but since that hemisphere is tilted away from the sun, it still feels like winter.



The second diagram shows the northern hemisphere pointing toward from the sun. This would be summer in the northern hemisphere; more direct sunlight, warmer days, and more daylight hours.

It also shows the southern hemisphere pointing away from the sun. This would be winter in the southern hemisphere; less direct sunlight, cooler days, and shorter daylight hours.

EVIDENCE #3: The changing location of the Earth in its revolution around the sun results in the different seasons. The northern hemisphere will have summer, while the southern hemisphere has winter.

Original source: http://www.nsta.org/publications/news/story.aspx?id=53136

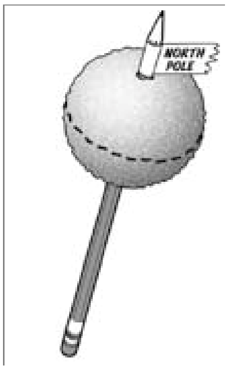
Q: What causes the seasons?

A: Isn't it obvious? The Earth is close to the Sun in winter and far from the Sun in summer. No, wait…that's the wrong answer, even though it's a commonly held belief. Before we get to the correct answer, let's figure out why the first answer I gave is wrong. If being close to the Sun causes summer on Earth, then all parts of the Earth should experience summer at the same time. That doesn't happen, though. While it's summer in the northern hemisphere, it's winter in the southern hemisphere, and vice versa. Also, it turns out that the Earth is closest to the Sun in January and farthest from the Sun in July. If distance from the Sun determined the seasons in the northern hemisphere, shouldn't the Earth be closest to the Sun in July and farthest from the Sun in January? Yep. So, throw that distance explanation out the window.

It's in the Tilt

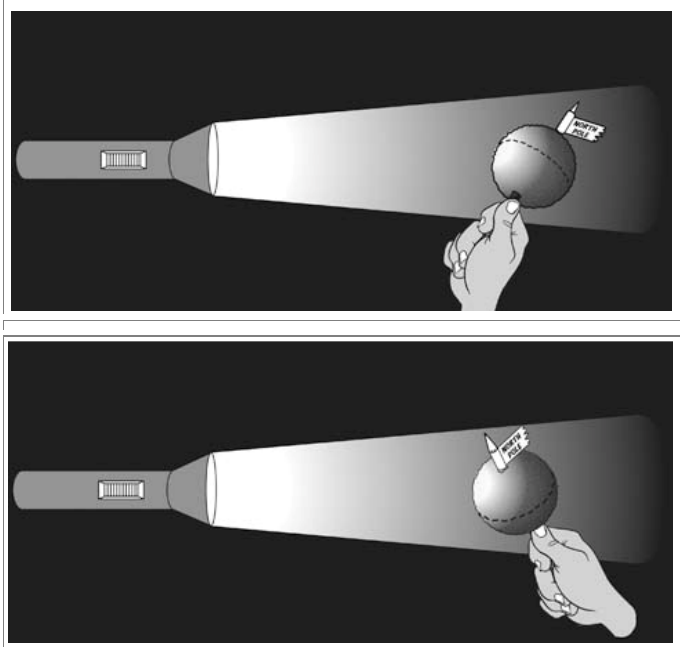
To understand the correct answer, get a pencil or pen, a Styrofoam ball, and a flashlight. Skewer the Styrofoam ball with the pen or pencil and draw an "equator" on the ball so you have a tiny representation of the Earth. See Figure 1.

Figure 1. A Styrofoam ball model of Earth. Figure illustrations by Brian Diskin.



Turn on the flashlight and set it on a table so it shines on your model Earth. Darken the room. Now tilt the "Earth" toward the flashlight and then away from the flashlight, noting how much light shines on the northern hemisphere in each case. See Figure 2.

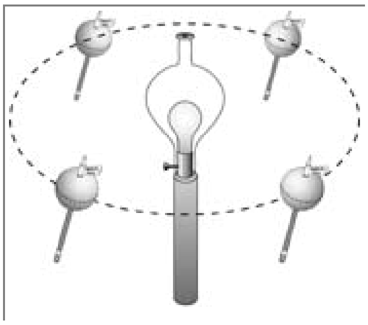
Figure 2. How much light shines on different parts of the Earth for different tilts.



If the flashlight were the Sun, you could say that when the Earth is tilted toward the Sun, the northern hemisphere receives a lot of direct sunlight, and when the Earth is tilted away from the Sun, the southern hemisphere receives a lot of direct sunlight and the northern hemisphere receives less sunlight. Now, if only the Earth were tilted, we would have an explanation for the seasons. Lucky for us, the Earth is tilted at an angle of about 23.5 degrees with respect to its plane of orbit around the Sun.

You can model this by replacing your flashlight with a table lamp with the shade removed, and then moving your Styrofoam Earth around the lamp as shown in Figure 3.

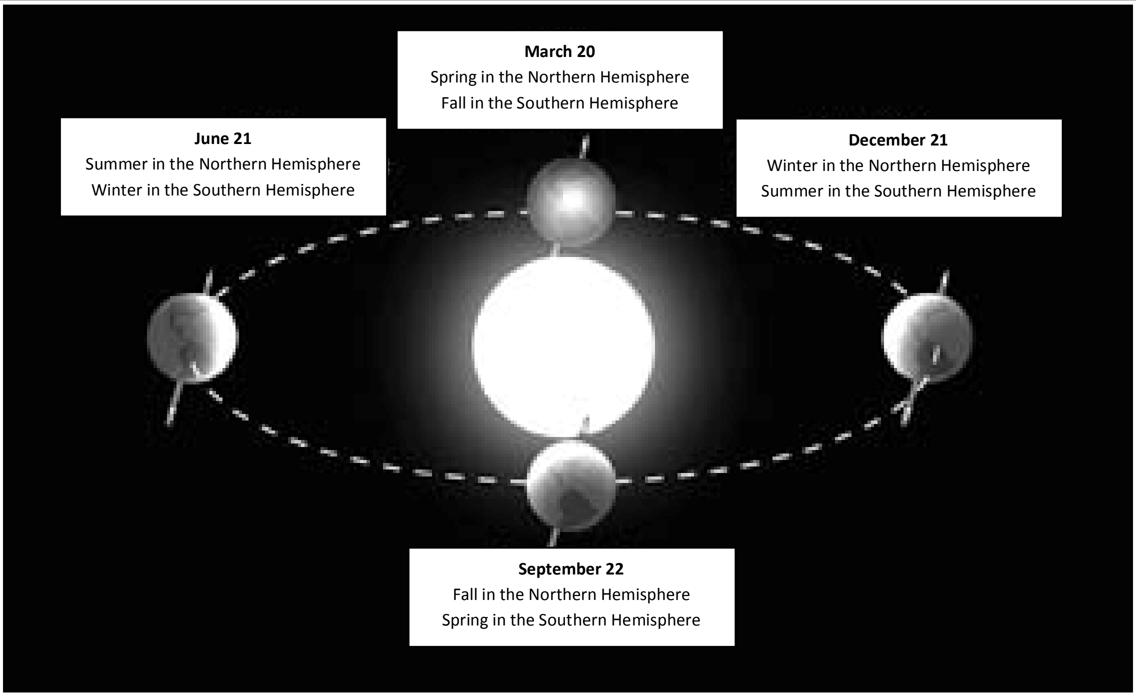
Figure 3. Earth maintains a constant tilt as it moves around the Sun.



Note that the Earth always tilts in the same direction as it goes around the table-lamp Sun. At one point, the northern hemisphere is getting lots of direct sunlight, and on the opposite side of the orbit, the southern hemisphere is getting lots of direct sunlight.

Figure 4 shows a drawing (not to scale!) of the real Earth and Sun throughout the year.

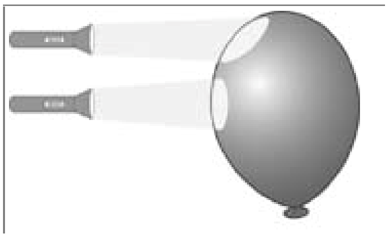
Figure 4. The changing location of Earth in its revolution around the Sun results in the seasons.



Shine On

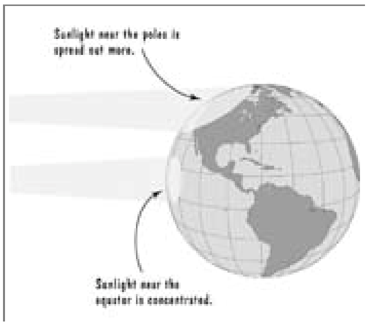
Note that in fall and spring (Figure 4), sunlight hits all parts of the Earth the same, or does it? If that were true, wouldn't the north and south poles be just as warm as the equator in fall and spring? Grab your flashlight again, and get a round balloon. Blow up the balloon and tie it off. Then shine the flashlight on the balloon from the side. First shine it on the center of the balloon and then move up and shine it on the top part of the balloon, as in Figure 5.

Figure 5. Light hitting a round object spreads out more in some places than in others.



Note that the light from the flashlight is more spread out when you shine it on the top part of the balloon and more concentrated when you shine it on the center of the balloon. This same thing happens with sunlight and the Earth. Sunlight hitting the equator is much more concentrated than sunlight hitting the poles, so the equator is always going to be warmer than the poles. See Figure 6.

Figure 6. Sunlight hitting the equator is always more concentrated than sunlight hitting the poles.



So, the tilt of the Earth is what causes the seasons, and uneven distribution of sunlight on the Earth keeps the poles cold and the equator warm. One last thing. The Earth does not always tilt in the same direction. The tilt of the Earth "precesses," or moves in a small circle, just as a spinning top does as it starts to slow down. What this means is that once the Earth is halfway through its precession, we'll have summer in January in the northern hemisphere! Not to worry, though. It takes about 26,000 years for the tilt of the Earth to complete one precession. Therefore, there won't be any significant calendar-season changes to make for at least the next five thousand years. Time enough to adjust, I think.

Bill Robertson (wrobert9@ix.netcom.com) *is the author of the NSTA Press book series,* Stop Faking It! Finally Understanding Science So You Can Teach It.

Resources

Robertson, W. 2005. *Air, water, and weather*. Arlington, VA: NSTA Press.