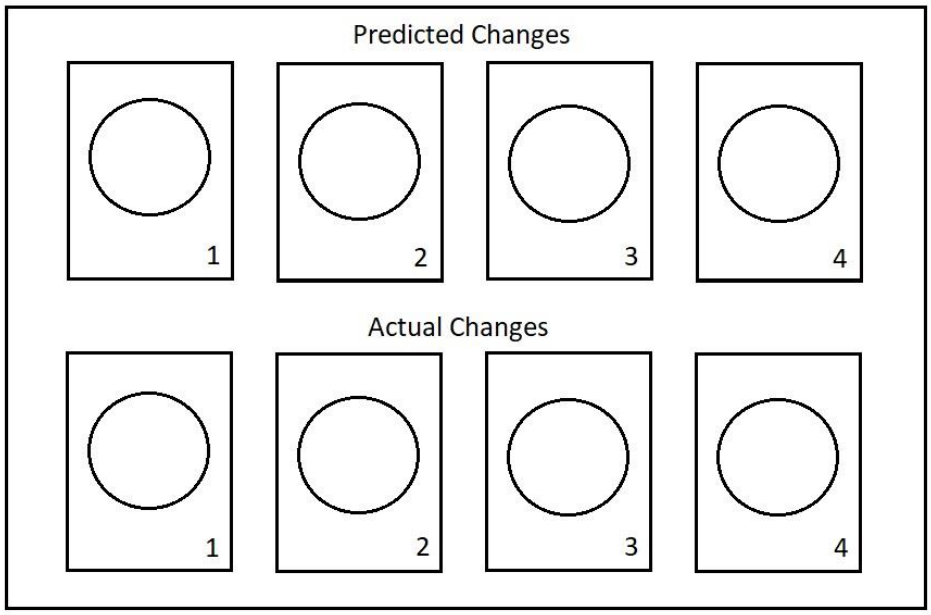
Dr. Daniel Barth – AstronomyForEducators@gmail.com

How Do You Know? – Episode #2:

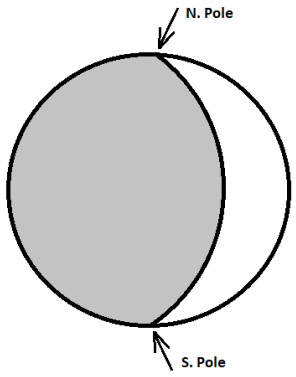
How Do Lunar Phases Work?

Part 1: Predicting Lunar Phases

Let's start with some very simple activities that will engage people in the study of the night sky. This first activity requires just pen and paper, and is best conducted during the ***waxing moon***, the 2-week period when the Moon grows brighter and more fully illuminated each night. The waxing moon is also visible each night just after sunset, meaning that anyone observing the sky does not have to stay up late.



This activity generally starts with the parent, teacher, or astronomer showing the student what the Moon looks like tonight. The student copies the phase of the Moon by drawing the ***terminator***, the line that separates light and shadow. For our purposes, always draw the terminator starting at the top or 'north pole' of the Moon, and finishing up at the bottom, or 'south pole of the Moon.



Drawing the Moon in its ***waxing crescent phase*** as it appears just 2-3 days after the new moon illustrates several things to the student. It is often easy in the crescent phase to see the entire disk of the Moon. This shows us that the shape of the Moon itself does not change (the Moon is always a sphere), but the amount of the Moon illuminated by sunlight does change.

With careful observation we can see that the ***terminator*** always stretches 180 degrees – from the Moon's north pole to its south pole – no matter how the Moon appears tilted with respect to our horizon.

The next step is to ask the student to draw in the top row of boxes what they think the Moon will look like over the next 7-10 days. I ask my students to do this ***in ink***, so that the prediction cannot be changed. Standards-based education has given students a tremendous fear of 'being wrong'. This is an excellent opportunity to teach students ***about science culture.***

> We do not do science to prove we are right.
> Rather, we do science ***to become right.***

Every student should be praised for their prediction – it is the effort (and the risk!) that must be rewarded here, not a 'correct answer'!

Over the next week or so, the students can go outside every 2-3 days and look at the Moon, sketching the phase that they see in the boxes in the lower row. This process provides several valuable insights to everyone involved. Science is not an instant process; it cannot always be boiled down into a 1-hour activity suitable for a single class period. Students will have to contend with clouds and weather, too; science sometimes proceeds from incomplete data! Although the sky is our laboratory, we do not control it. Our young scientists must plan their observing time and go out when the Moon is visible; the phenomena will not wait for us and there is no redo button!

It is fascinating when the week of observing is over to compare what we thought would happen to what we actually observed. Once again, it is critical at this point for the teacher or parent to emphasize what we have learned about the Moon and its phases instead of looking for easy 'right vs. wrong' answers. Remind the child that in science, ***virtually all first predictions are incorrect!*** Science is an adventure in learning more precisely how the world works!

Part 2: Modeling the Earth-Moon System

If you have completed the first part of our activity and looked at the Moon for a week or two, you should now have a pretty good idea of ***what happens next*** in the sky. You can look at the lunar phases on night, and know with certainty what will happen to the lunar phase over the coming days and weeks. Even so, the charts and models that show how the lunar phases change have a major weakness – they do not tell us ***how the lunar phases work!*** The next part of our activity will help us understand how the lunar phases work, and what causes them to appear as they do. We will do this with a simple model of the Earth-Moon system.

> Charts and models have a major weakness;
> they do not tell us ***how lunar phases work!***

To complete this model, I use ping-pong balls, black spray paint, colored markers and a few other items. Some parents (and teachers!) have noted that it may be difficult for them to get three ping pong balls per student or group, and that they have reservations about using spray paint. This is perfectly understandable! Any ball will do! You could use plastic golf balls, rubber balls, base balls – any light-colored ball will do fine. You can even make balls out of modeling clay, air-dry clay, or salt dough – try to make them as round as you can, but having a perfect round shape isn't necessary!

I begin with a ping pong ball and some wide blue painter's tape. Cut a piece of tape and wrap it carefully around the equator of the ball. (Tip: if there is a logo on the ball, make sure it is visible <u>above</u> the tape!)

With the ball wrapped, you are now ready to paint one side. I use a stick, even a pencil or a ruler and stick the wrapped ball to one end. This lets me paint without getting paint on my hands or clothes. Be sure to paint outside in the fresh air! A thin coat of flat black paint works best and dries in just 10 minutes.

If you are preparing a number of these balls for a class (2 per student), you can tape them all, then place them inside a cardboard box and spray the paint down inside. This paints all the balls at once, and you don't have to trust your students with cans of spray paint! Of course, if you do not want to use paint or do not have it available, you can use black marker, even crayons, as long as one side of the ball is uniformly dark. (Tip: Always use permanent markers! Water based marker will come off on everyone's hands and make a mess!)

With two balls painted, you can now use markers to draw on the features of your planet and moon. Don't worry about the 'art' aspect. You can draw very realistic models of our Earth and Moon, but that is not necessary! Any planet with random oceans, continents, polar caps, etc. will work just fine. For your moon, shade in maria (dark regions), highlands (bright regions), some craters, etc. If your students have 'art anxiety', tell them to make up their own planet. Have them make up names for oceans, continents, and lunar features – even name their planet and its moon!

Once you glue your planet and moon models onto a base, they will be ready to use. We often use plastic bottle caps for bases, coins, poker chips and the like also work well. Teachers: if you use plastic poker chips for the base of the model, you can glue a strong magnet to the bottom which will allow you to display your models on a white board where everyone can see them! For students to be able to see how the models are arranged on the whiteboard is often a great help in the classroom! Some models such as the ones you see here can be very accurate. One of these shows the new world with north and south America, the other shows the south Pacific with Australia, the Indonesian archipelago, and eastern Asia! (Tip: clouds and storm systems were added using a white correcting pen!)

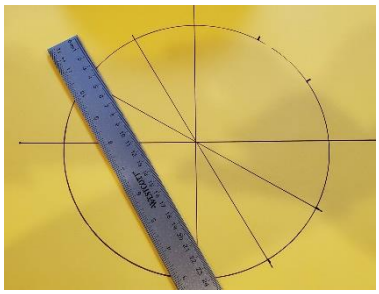
You may wish to expand your model solar system! You can add a solid yellow model for the Sun, a plain, half-black, half-white model for cloud-shrouded Venus. You can even add an outer planet such as Mars, Jupiter, or even Saturn with an index card cut out to make the ring system!

There are many ways to explore our solar system with these models including, seeing how the lunar phases work, why inferior planets (closer to the Sun than us) show phases while superior planets (farther from the Sun than Earth) do not. You can even prove that the old ***Geocentric*** (Earth-centered) model of the solar system doesn't work, but the ***Heliocentric*** (Sun-centered) model does. We will take a look at that on another show!

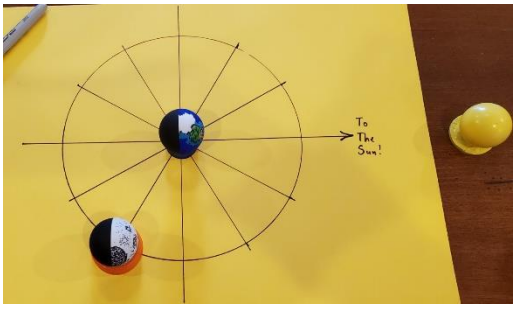
Part 3: Exploring how the Lunar Phases Work

In the second part of our activity, we created lovely models of planets and moons! This activity has been a favorite with my students for more than 30 years! If your children and students are like mine, once they mastered making a single planet and moon, they were hardly satisfied – my classroom often became filled, worlds without end, and models as far as the eye could see! Let's see how we can use these models to show children how the lunar phases actually work. If you are a teacher, you will probably want to have students make their models as one project, and then experiment with them on another day. If you are an astronomy outreach person, you may wish to have some sets of finished models ready for people to work with when you start your activity night.

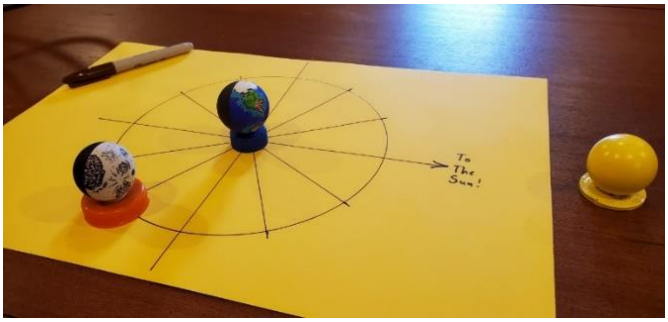
With your models made, all you need now is some construction paper (bigger sheets work better), and a few markers. We'll start by using a plate or a compass to draw a large circle on our paper. Once we have the circle, use a ruler to divide it up into 8 pieces, just like you might cut up a pizza! I used an old clock to draw my circle, the hours provided nice marks to precisely divide my circle into 12 even parts. You can easily do 8 parts by drawing a vertical and horizontal line through the circle, then evenly divide diagonally into 8 parts.



Once I had the circle drawn, I used a ruler to draw my lines, being sure to pass through the center each time. If you are working with younger children, don't be too fussy! Even if the circle is a bit off center or the circle isn't evenly divided into equal parts, this model will still work fine. The design is very forgiving!



With the circle now drawn and divided on our construction paper, draw an arrow to the right and label it 'To the Sun!' Whether or not you have made a Sun model, it is important to know where your Sun is supposed to be. This is important because the Sun acts like a 'distant candle' that illuminates exactly half of each planet or moon (the day time side!) and leaves half of each body in darkness (the night time side!) It is critical to make sure that the lighted half of your planet and moon ***always point directly in the Sun's direction!*** If your planet and moon are not pointed correctly, you will not see the lunar phases as they appear in the night sky!



One thing to point out to students here, is that as we look at the model, we do not really see phases as such. Have the students play with the model for a bit, and ask them to see if they can get the model to show phases just as we diagramed them using our salt-dough models. Chances are, the students will not be able to do this (most adults can't solve this puzzle, either!) So, how is it done?

One thing to point out is that when we look at a model like this, we do not readily see changing phases!

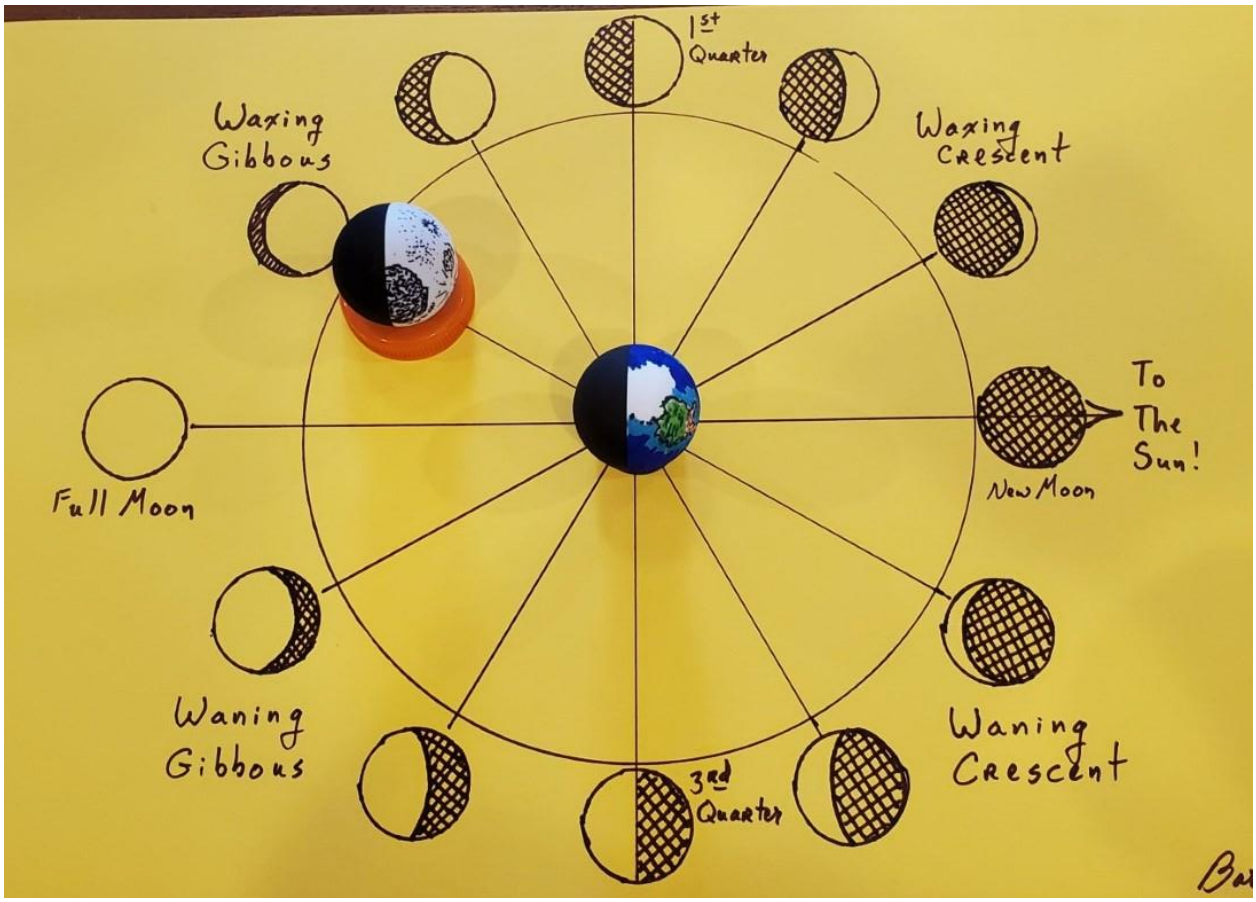
Our model shows the Sun, Earth, and Moon, as well as the Moon's orbit around the Earth; so why can't we see the phases of the Moon as they appear in our diagram, and in the correct order? The answer is really rather simple – so simple in fact, that most people overlook it. We haven't put ourselves into the model! As human beings, we stand on the Earth's surface and look out into the night sky! It is this unique point of view, standing on the Earth and looking up, that gives us our perspective of the lunar phases in the night sky! I've added a little figurine here to illustrate this point.

For us to be able to see the Moon as it appears from the Earth, we have to put our head down on the table with our eye looking just over the Earth at the Moon. When we put our eye into the model in the same position as we ourselves occupy on the Earth, then we immediately see the lunar phases just as we would in the night time sky! All we need to do now is to look, and draw each phase of the Moon as we see it.

If you are working with adults at an astronomy outreach event, ask people to put their mobile phone camera just behind the Earth, pointing at the Moon. They can then take a photo of the Moon in each position. Once they have ***one photo*** of each position, have them scan through the photos rapidly – they will see the changing phases of the Moon appear on their phone!

To do this, begin with the Earth in the center and the Moon at the 3 o'clock position - be sure both lighted faces are pointing ***to the Sun!*** Place your eye (or camera) down near the Earth and you should see the ***new moon phase*** – you will only see the night time side of the Moon. Draw a small circle and sketch in the moon phase as you see it. Continue to move the moon model to each new position, moving anti-clockwise around the circle. Each time, put your eye down and make a sketch of the phase you see!

When you are done with this, you should have a chart of the lunar phases that is very similar in all important respects to the one we made with salt dough earlier. It shows the phases in their correct order. It shows the terminator, the line of sunrise and sunset sweeping across the Moon's surface from east to west. It shows how the Earth, Sun, and Moon work together along with the Moon's orbital motion around the Earth – and our special place on the Earth's surface looking out into space all create the lunar phases that we see in the night sky!



There are three things that combine to create the lunar phases that we see.

1. The Sun is a *single candle* that lights one half of any planet or moon, and ***always the same side!***
2. The Moon's ***orbital motion around the Earth*** every 28 days.
3. Our own privileged position on Earth's surface, viewing the Moon from ***the center of its orbit!***

Now you know – ***How You Know!***

For More Information:

The activities and materials provided free for the ***How Do You Know?*** program are based upon Dr. Barth's award-winning book: ***Astronomy For Educators.***

This book is used as a resource in more than 3800 schools across the United States and in more than 40 countries world wide. The book is published as an *Open Educational Resource Text* by the University of Arkansas Library Press.

You are welcome to download a free copy! If you would like to help Dr. Barth, please take our 5-minute survey! All responses are anonymous and information is used in STEM education research and in planning upcoming books in this series.

Thank you for participating!

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Contact Dr. Barth at: AstronomyForEducators@gmail.com

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