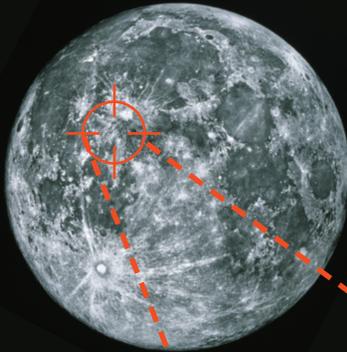


I N V E S T I G A T I N G

Astronomy

C O N N E C T I O N S

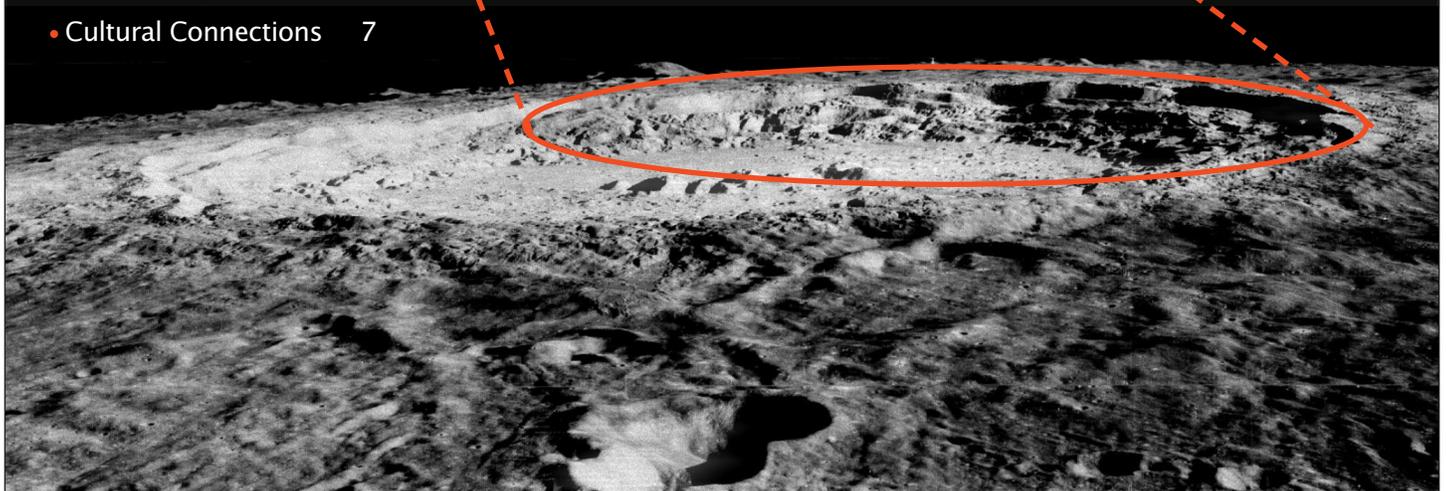


Investigating the Sun–Earth–Moon System

Craters on the moon retain their form because there is no erosion due to wind or water. Copernicus crater is relatively young—only 800 million years old...
See story on page 2.

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Sizing Up the Moon

Materials You'll Need

- 2 cans of Play-Doh®
- 2 pieces of scratch paper
- Butter knife for each participant
- Pencil
- Ball of string

Birthday Moons

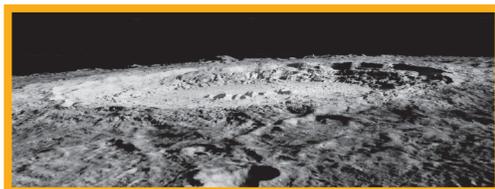
Ever wonder what the phase of the moon was when you (or a friend or family member) were born? What phase will it be on your next birthday?

Go on the Internet to find out:



[<http://tycho.usno.navy.mil/vphase.html>]
 [<http://stardate.org/night sky/moon/>]

On the Cover



Part 1: Predicting

- 1** Remove the Play-Doh from one can. Roll it into a solid ball.
- 2** Consult as a group/family about how big you think Earth is compared to the moon. Then pinch off some clay and form two balls that represent the relative size of Earth and the moon. This is your size prediction.
- 3** Mark "Earth" on one piece of paper and "moon" on another. Place the appropriate ball of clay on each of these pieces of paper.
- 4** Place the Earth ball at one end of a table, and then decide, as a group/family, where on the table to place the moon ball to represent the distance from Earth to the moon's orbit. This is your distance prediction.

Part 2: Modeling

- 1** Open the other can of Play-Doh. Roll it out into a hot-dog shape.
- 2** Cut it into 5 equal pieces.
- 3** Cut each of these pieces, in turn, into 10 equal pieces. You should now have 50 more or less equally sized pieces.

4 Since the 50 pieces are probably not exactly the same, put them in the center of the table and choose one, average sized piece. This piece represents the moon.

5 Roll the remaining 49 pieces together into one large ball. This represents the Earth.

6 Place this Earth next to your "prediction" Earth. Are they close in size? Most people tend to overestimate the size of the Moon, so they end up with an Earth that is too small.

7 Our moon is approximately 30 Earth diameters away from Earth, so carefully count, marking with your finger, 30 Earth diameters, one at a time. Or, since the distance around a circle (the circumference) is $\pi \times \text{diameter}$, and π is about 3, estimate 30 diameters by wrapping a piece of string around your Earth 10 times. Unwrap it, and stretch it out from Earth. Then place the moon at the other end of the string. Was your distance prediction close to the actual distance? ★

Craters on the moon retain their form because there is no erosion due to wind or water. Copernicus crater is relatively young—only 800 million years old—compared to the rest of the lunar surface that formed some 4 billion years ago. This image was taken by the Apollo 17 orbiter. Copernicus is a large crater, measuring 93 km (55 mi.) across and 3.8 km (2.3 mi.) deep. This crater also has a raised rim, and you will notice that large blocks of material along the edge have slumped downward, forming terraces. Unlike Barringer Crater on Earth, Copernicus has three isolated mountains in its center, each one over 1,000 m tall. Exploring such a crater would be difficult to do on foot or in a vehicle, as the bottom of it is filled with a rough and jumbled mass of rock! (Credit: NASA)

A Family Lunar Calendar

Along with many Native American calendars, the Moslem, Jewish, Hindu and Chinese calendars in use today are all based on lunar cycles. (The Chinese calendar is by far the oldest of these, believed to date back to 2698 B. C.) Lunar calendar months begin with the new moon or the first sighting of the crescent moon after the new phase. Because the moon goes through one complete set of phases in 29.5 days, a lunar month does not quite match our modern calendar. There are similarities, however. Just as months on our calendar have unique names, each lunar month had a name based on either a religious significance or a natural change in the season.

What to do

★ Consider the list of calendar names from two different Native North American groups. The Cheyenne lived on the plains of the central part of America, and the San Juan Pueblo is in the high desert mountains of New Mexico. By looking at the names for their months, you could make some guesses about the differences in climate for these two regions.

★ Discuss events that are significant to your own family that may or may not be linked to the climate. Then brainstorm some ideas for what you might call each month and create a calendar that is unique to your family. (For example, does your family have multiple birthdays in January? Perhaps the January moon would become the Birthday moon. Do you take a family vacation in the same month each year?) ★

Modern Calendar Month	Almanac Calendar Month	Cheyenne Calendar Month	San Juan Pueblo Calendar Month	Family Calendar Month
January	Winter Moon	Hoop and Stick Game Moon	Ice Moon	
February	Trapper's Moon	Big Hoop and Stick Game	Coyote Frighten	
March	Lenten Moon	Light Snow Moon	Lizard Moon	
April	Planter's Moon	Spring Moon	Leaf Split Moon	
May	Milk Moon	Time When Horses Get Fat	Leaf Tender	
June	Rose Moon	Moon When Buffalo Bulls Rut	Leaf Dark	
July	Summer Moon	no name	Ripe Moon	
August	Dog Days Moon	Time When Cherries are Ripe	Wheat Cut	
September	Harvest Moon	Cool Moon	All Ripe Moon	
October	Hunter's Moon	Moon When Water Begins to Freeze on the Edge of the Stream	Leaf Fall Moon	
November	Beaver Moon	Freezing Moon	All Gathered Moon	
December	Christmas Moon	Big Freezing Moon	Ashes Fire Moon	



Star Witness

Fred Espenak, aka Mr. Eclipse

Even though there are countless places to visit and wonders of nature to see on Earth, Fred Espenak believes that everyone should have “witnessing a total solar eclipse” on their list of things to do before they die. Part of his job at NASA’s Goddard Space Flight Center involves calculating the details of eclipses, from how long they will last to where on Earth the eclipses will be visible, for both NASA and the International Astronomical Union. His related hobby is traveling the world to photograph and experience first hand these natural wonders. He got hooked on the pursuit of eclipses while still in high school. In Mr. Espenak’s own words, this is how it all got started:

“In 1970, I was a high school student and an amateur astronomer so I thought that the solar eclipse passing along the east coast of the U.S. would be a once-in-a-lifetime experience that I couldn’t pass up. I convinced my parents to loan me their car for the 500-mile drive, in spite of the fact that I’d only been driving for a few months. I wanted to drive to Florida where the eclipse lasted longer, but I was exhausted by the time I reached North Carolina. And the little motel I found in Windsor was an ideal place to watch the eclipse. Many others had the same idea, because the field behind the motel was filled with people, telescopes, and cameras on eclipse day.

I had read all I could about solar eclipses, but I was quite unprepared for the experience of totality. It was electrifying, sublime, awesome, and humbling all at the same time. I managed to make a couple photographs of the total eclipse, but they

pale in comparison to the images of the event that were burned into my mind’s eye. I knew that I just had to see another eclipse because it all happened way too fast. Before my equipment was even packed into the car, I was already dreaming about traveling to Quebec for the total eclipse in 1972! ”

You might think, “once you’ve seen one, you’ve seen ‘em all,” but Mr. Espenak would disagree with you. Because of the circumstances of solar eclipses, they are only visible from a narrow band along the surface of the Earth. Fortunately, Espenak loves to travel. He’s been to every continent on the globe, including Antarctica, just to experience solar eclipses in the regions where they’re viewed best. To date, he’s seen 20. If you’ve only seen a partial solar eclipse or a lunar eclipse, you may question Mr. Espenak’s passion. But this is his response.

On a scale of 1 to 10, a partial solar eclipse is interesting, and he’d rate it a 6. An annular eclipse is a special case, as it’s not quite a total, but is not like a partial, either. During an annular eclipse, the Moon is a bit too far from Earth to appear large enough to completely block out the light of the Sun. So what you see is a silhouette of the Moon against the Sun, with a brilliant ring of sunlight around the edge of the Moon. Because an annular eclipse is such an unusual event, Mr. Espenak would rate this a 9. But a total solar eclipse is completely off the scale. He gives that a 10,000!

Mr. Espenak frequently goes to eclipse sites with large tour groups. There is usually a mix of eclipse chasers and first-time observers in the group. Even for the seasoned observer, the experience of a total solar eclipse can be overwhelming,

Credit: F. Espenak



and reactions during totality range from applause to tears. Mr. Espenak explains it this way: Think about something that you would love to do, like exploring the Grand Canyon, or gazing at the Mona Lisa, and then imagine that you could only do it for 2 minutes every 2 years! You would definitely savor the experience. You would look forward to your next chance with great anticipation. As for solar eclipses, will the weather will cooperate, or will the clouds force you to wait for the next one?

Of the 20 total eclipses that he’s seen, so far, Mr. Espenak has two favorites. His first, in 1970, was wonderful, because he didn’t know what to expect and that is where he caught the eclipse-chasing bug. The total eclipse in 1991 was also stunning, with totality lasting over 6 minutes. The event was extremely long, it was nearly overhead, it was near sunspot maximum, so there was lots of interesting detail in the corona, and there were four planets visible in the darkening sky during totality.

Mr. Espenak is already making plans to see the next total solar eclipse to grace the continental United States. It will occur on August 21, 2017 and will be visible along a diagonal path from Oregon to South Carolina. Ten years may seem like an eternity, but Mr. Espenak thinks it’s not too early to start planning a summer vacation that will put you somewhere in the path of the eclipse! ★

Hot
Link

[<http://www.mreclipse.com/SEphoto/SEgallery1.html> (for info on the 1970 eclipse that got him hooked) <http://sunearth.gsfc.nasa.gov/eclipse/SEcat/SEdecade2011.html> (for info on the 2017 total eclipse)]



Sky Watch

Eclipses

“On the day of the new moon, in the month of Hiyar, the sun was put to shame, and went down in the daytime, with Mars in attendance.”

One of the earliest written records of an eclipse of the sun, on May 3, 1375 BC, found in the city of Ugarit in Mesopotamia.

Ancient cultures were far more in tune with the rhythms of the cosmos—the motions of the sun, moon, planets, and stars—than we are today. They told time by the daily passing of the sun and used the interval between full moons to gauge longer periods of time. The rising and setting of certain stars marked the beginning or passing of seasons. The skies were orderly and dependable, except when an eclipse occurred. When that happened, chaos reigned, and our ancestors prayed to their deities and begged for the moon or the sun to be returned to the sky.

But in our modern technological world, we understand what causes solar and lunar eclipses. When the moon is exactly aligned with the sun and Earth during a full or new moon, a lunar or solar eclipse will occur. Since the orbit of the moon around Earth is tilted 6° to the Earth-sun plane, exact alignment is quite rare.

Eclipses are named for the celestial body being darkened, so a solar eclipse occurs when the new moon moves between sun and Earth, obscuring the face of the sun completely. The shadow of



Solar eclipse (Credit: NASA)

the moon is cast onto Earth, but the shadow is quite small, and the eclipse is not seen over our entire planet. Your chances of seeing a total eclipse of the sun while you're at school are very slim.

A lunar eclipse happens when the full moon slips into the shadow Earth is casting out into space. It is more common to see a lunar eclipse since the moon slips into the Earth's extensive shadow. The moon gradually darkens and sometimes turns a dull red for an hour or more.

The chart below presents the time and place total eclipses of the sun and moon can be seen from Earth in upcoming years. ★

Total Eclipses 2006-2010

Date	Type	Duration	Where Visible
2007 Mar 03	Lunar	1h 14m	Americas, Europe, Africa, Asia
2007 Aug 28	Lunar	1h 31m	Asia, Australia, Pacific, Americas
2008 Feb 21	Lunar	51m	Pacific, Americas, Europe, Africa
2008 Feb 07	Solar	2m 12s	Antarctica, E. Australia, N. Zealand
2009 Jul 22	Solar	6m 39s	Asia, Pacific Ocean, Hawaii
2010 Jul 11	Solar	5m 20s	South America
2010 Dec 21	Lunar	1h 13m	Asia, Australia, Pacific, Americas, Europe



The Moon at Your Fingertips

Question:

Have you ever noticed how large the moon appears to be when it is near the horizon?

The size of the moon seems to depend on whether the moon is near the horizon or high in the sky. That difference has to do with how our brains interpret information. Actually, the moon does not change size over the course of a single night. Neither the moon's size nor its distance from us changes as Earth rotates. All that has changed is that we compare the moon with Earth bound objects, such as buildings, mountains, or trees, when it is close to the horizon. This causes our brains to interpret the moon as being larger than when we see it higher in the sky.

Photographs like Figure 1 are taken with telephoto lenses, making the moon appear large on the horizon, to match how your brain interprets what it sees. But if a photo were taken with a standard lens pointing at the moon on the horizon, and then again from the same spot a few hours later, the moon would appear the same size in both photos.



Figure 1: Photographs like this make the moon appear large on the horizon. (Credit: NASA)

Make an Observation:

The next time you see a full moon, look at it when it is near the horizon. Try measuring its apparent size. (The moon appears about half as wide as your pinky finger held at arm's length.) Then, a few hours later, when the full moon is high in the sky, try it a second time. At first glance, the moon may look much smaller than when it was just rising, but again extend your pinky finger with your arm stretched out. The moon will still appear about half as wide as your pinky.

By the way, if Earth's diameter is nearly 4 times that of the moon, how big would Earth look in the sky if you were standing on the moon?

(Answer: If the moon appears to be half a finger's width when viewed from Earth, then Earth would be as wide as two pinky fingers held at arm's length when viewed from the moon.) ★



Figure 2: Earth as seen from the moon (Credit: NASA)



Cultural Connections

Around the globe, cultures have made connections to the moon through their sky lore and mythology. Below are some brief summaries of stories from around the world describing figures perceived in the face of the full moon and how those images got there. Can you see the toad, the fox, the woman, the boy and girl, or the rabbit? Look for them during the next full moon.

Fox—A Story from Peru

All Fox could think about was getting to the moon. After braiding a rope from grass long enough to reach to the moon, he got help from the birds to fly one end of the rope up to the moon. Once that was done, Fox climbed up the rope. The birds say they can still see Fox in the full moon.

Rabbit Moon—A Story from the Aztecs of Mexico

In ancient times, a god chose to set himself on fire and jump into the sky to light the cold, dark world. He became the sun. A second god, jealous of the praise that this new sun was getting, did the same. This was too much light, so another angry god threw a rabbit at the second sun's face to dim his light, making him the moon.

Moon Woman—A Story from Polynesia

Have you ever seen a rainbow at night formed by moonlight instead of sunlight? Hina, a Polynesian woman, who was on her way to get some fresh water did. She had always wanted to live in the heavens, so she walked along the rainbow and didn't stop until she reached the moon. She lives there now and can be seen beating her tapa board to make cloth.



Moon Woman (Credit: ASP for all)

Jack and Jill—A Story from Scandinavia

Hyuki (Jack) and Bil (Jill) were sent up the hill to fetch a pail of water from a magical well. (Water from this well inspired both poetry and prophecy.) The children were spotted by the man who carries the moon across the sky each night in his chariot. He scooped them up into his chariot and carried them away. The two children can still be seen there today—bucket, pole, and all.

The Toad in the Moon—A Story from China

Heng O found out that her husband, Sheng I, had the secret of immortality. When she found the potion, she drank it and immediately flew out the window up to the moon. Sheng I was so angry with what she had done, he turned her into a three-legged toad. ★



Fox Moon



Rabbit Moon



Toad in the Moon