

Chapter 4

Aristotle

So how do we explain all this information we have learned so far? We know the sun rises in the east and sets in the west. But why does it rise and set? What makes the sun move?

The way people typically answer questions like these is to invoke supernatural powers. One example of this is the Greek myth of Helios:

The sun rises and sets because the sun is the glowing chariot of a god, Helios.

Helios's job is to hitch up the horses every morning and ride his chariot across the dome of the sky.

In cultures all over the world, unseen supernatural powers -- gods, spirits, sprites, and other entities -- are what make the world work. Of course, relying on gods to make the world work has an uncomfortable aspect to it. Suppose Helios gets tired of riding the chariot across the sky 7 days a week, 52 weeks a year? If that happens, the sun may not rise tomorrow; the Earth will grow cold, crops will die, and humanity will starve to extinction in the freezing dark. If the world is run on the whim of the gods, then we had better keep those gods happy so that they keep doing what we need them to be doing, such as making the sun rise and set. In some cultures it was even believed that the sun god required human blood in order to be able to keep rising and setting, and so people were sacrificed in order that the sun would always rise.

Explaining the workings of nature in terms of supernatural powers also gives rise to the possibility of magic. Just as we may need to keep the big gods happy to ensure that the sun rises tomorrow, it may be that we can trick, form alliances with, or even coerce the small gods, spirits, sprites, demons, and other supernatural beings that fill nature. For example, a rock may fall to the ground because it came from the ground -- the rock spirit yearns to return to the goddess mother Earth in whose bosom it once rested! But by tricking or forcing the rock spirit to stay away from mother Earth, we can cause the rock to

levitate. The right words, the right spell, the right wand -- and we can make rocks fly!
*Wingardium Leviosa!*¹

While the idea that the world is controlled by supernatural powers seems to be what people naturally gravitate toward, let us consider an alternative idea. This idea apparently is fairly radical, because it does not seem to crop up readily. The radical alternative to supernatural powers is this: *The world functions according to certain rules that are inherent in nature; no direct action by the gods, spirits, sprites, and demons is required.*

For example, imagine you have a large steel bolt and a piece of paper. You hold them out in front of you, and release them both at the same moment. The bolt falls directly and rapidly to the ground. The paper flutters and floats its way down, reaching the ground significantly later than the bolt. Why did this happen?

An explanation based on the view that nature is governed by supernatural powers might go something like this:

What is the bolt made of? Metal -- material that was mined from the ground, heated, forged, and hammered into shape. The bolt is a daughter of mother Earth, ripped from mother Earth against both of their wills. The spirit of the bolt yearns to return to mother Earth -- it never willingly left. Thus, when released, the bolt runs gleefully home to mother with joy in its heart.

Now what is the paper made of? Wood -- trees. Unlike the metal in the bolt, the material in trees leaves the ground of its own accord. It is not torn from Earth against its will. Thus the spirit of the paper does not seek so strongly to go to its mother whom it left willingly, and the paper, when released, only reluctantly returns to the ground.

Again, under this view of the world it is possible that we might persuade the paper spirit that it misses mother Earth, and we might convince the bolt spirit that mother Earth has grown to hate it in its absence. Thus we might cause the bolt to fall slower and the paper faster. That would be magic.

1 Levitation spell taught at Hogwarts School of Witchcraft and Wizardry -- J.K. Rowling, *Harry Potter and the Sorcerer's Stone* (Scholastic, 1997).

Now consider an explanation of the fall of the bolt and the paper that is based on our radical alternative view (that the world functions according to certain rules that are inherent in nature, without any direct action of the gods, etc.):

All materials on Earth are made of a combination of four basic substances or elements. These are earth, water, air, and fire. Each of these four has a natural place in the universe towards which it will move. The natural place of earth is the lowest spots in the universe. Water also tends down to low places, but not so strongly as earth. Air has no tendency downward. We can verify the tendencies of earth, water, and air easily -- we fill a bottle 1/3 full of sand, 1/3 full of water, and 1/3 full of air; shake it to mix the three, then let the bottle sit; the sand (earth) will move to the bottom, followed by the water next; the air will be on top. The final element, not in our bottle, is fire, which tends upward toward the sky. Thus water and earth have "gravity" (heaviness), fire has "levity" (lightness), and air is in the middle.

What is the bolt made of? Metal -- material that was mined from the ground, heated, forged, and hammered into shape. It is refined earth. You cannot get it to release water, air, or fire. Hold a match to it and nothing happens. It is just earth, and therefore has a very strong tendency to move down. You release it, and down it goes.

What is the paper made of? Among other things, wood -- trees. Trees grow in earthy soil, true, but trees also require water, air, and warmth and light. Wood is not pure -- it is a combination of elements. Paper, which is made from wood, is also a combination of elements. We can prove, for example, that paper contains fire within it -- paper burns. When paper burns, the fire in the paper is released; the material left behind, ash, is more earthy than the original paper was. Since paper contains multiple elements, it has some tendency to move down, thanks to the earth in it, but it also has some tendency to rise up, thanks to the fire in it. Thus paper does not fall to the ground as quickly as does the bolt.

In this explanation there are no spirits motivated by love or dislike. The bolt and the paper fall because of what they are made of, and because of some basic rules of nature -- rules of "gravity" and "levity". There is not so much room for magic here.

This “rules of nature” way of thinking appeared in ancient Greece 25 centuries ago. The ancient Greeks were a unique people who developed these kinds of ideas about the world -- and wrote them down. Most other peoples did not. The story of science has roots in the Greeks in ways that are not shared with any other people.

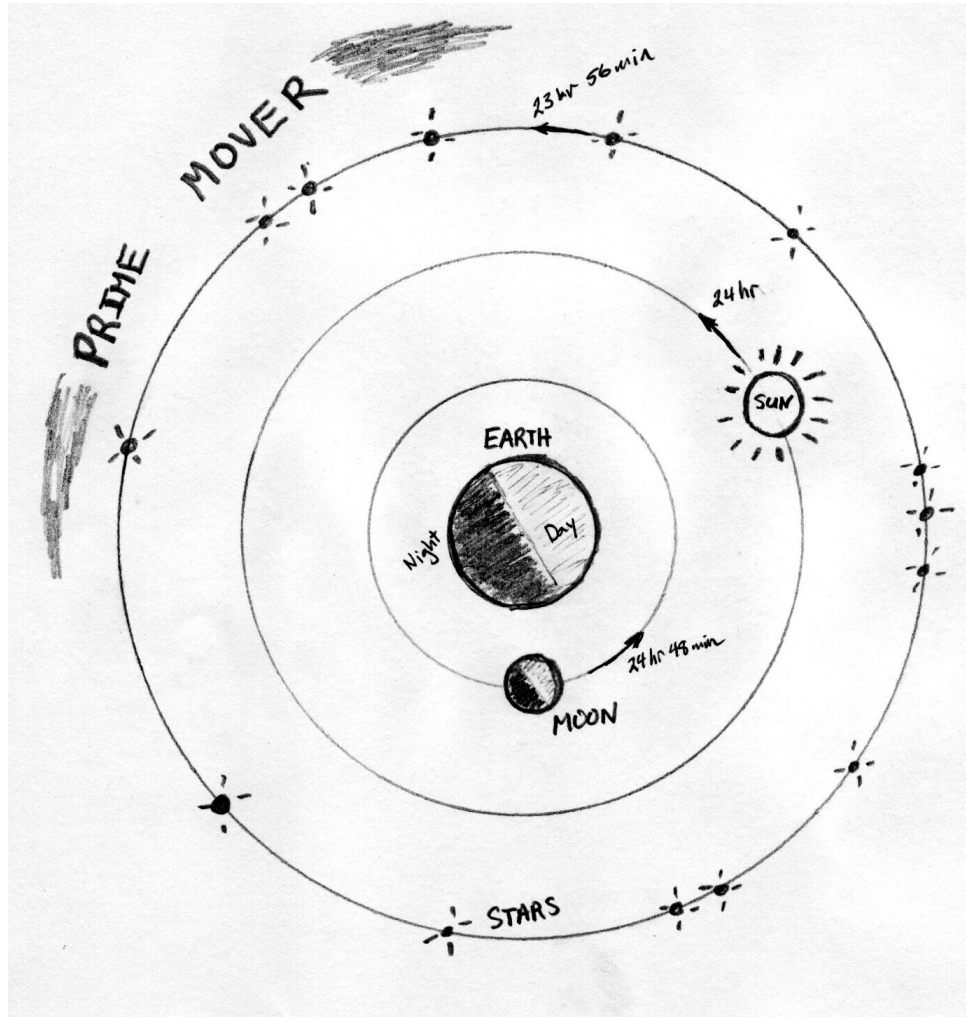
While many different ancient Greek thinkers contributed to the story of science, the ancient Greek most central to our story is Aristotle, who lived approximately 2300 years ago.² Aristotle wrote on many different subjects, ranging from what animals are like, to how the heavens work, to what is ethically good and bad. Aristotle probably knew just about everything there was to know 2300 years ago. His ideas would dominate science for almost 2000 years.

Aristotle developed theories about how the universe is structured and how it functions. His theories do a very nice job of explaining what we have learned so far about the heavens from talking to our grandmother and from four nights of observing the world with our eyes, a notebook, and a watch, namely:

- ✓ The sun circles our world once every 24 hours.
- ✓ The stars circle our world once every 23 hours, 56 minutes.
- ✓ The moon circles our world once every 24 hours, 48 minutes.
- ✓ The stars visible after sunset change in a yearly cycle.
- ✓ The moon changes in a monthly cycle.
- ✓ The constellations (stars) do not change.
- ✓ The cycles of the heavens do not change.

According to Aristotle, the universe looks something like the drawing on the next page. Our Earth lies unmoving at the center, or bottom, of the universe. The Earth is round. The sun, moon, and stars all circle the Earth. The stars circle most quickly (once every 23 hours, 56 minutes), the sun a little slower (once every 24 hours), and the moon the slowest (once every 24 hours, 48 minutes). Aristotle theorized that movement occurs

2 Aristotle was born in 384 B.C. (384 years before Christ) and died in 322 B.C. For dates before Christ I will use the abbreviation B.C. For dates after Christ I will use no abbreviation. So Aristotle died in the year 322 B.C., whereas Columbus discovered America in 1492, and the Declaration of Independence was signed in 1776.



Above: Aristotle's universe (sizes of objects and distances between objects are not to proper scale in this picture). The Earth is round. It is circled by the sun, moon, and stars, whose motions are powered by the Prime Mover. The sun illuminates the Earth and moon, causing day and night on Earth. The stars circle the Earth most rapidly, followed by the sun, then the moon, so speed is lost as motion progresses down from Prime Mover to Earth, with Earth sitting at rest.

The motion of the heavens is eternal – there was never a time when the motion did not exist and there will never be a time when the motion ceases. The sun will always rise. This is possible because the heavens are made of a substance different from what makes up the Earth. The Earth is made of four elements – earth, water, air, and fire – which exist in the region below the moon. The heavens are made of a “Fifth Element” not found below the moon. The Fifth Element is perfect and unchanging. Stuff made of the four earthly elements has a natural tendency to not move. Stuff made of the Fifth Element naturally moves in eternal circles.

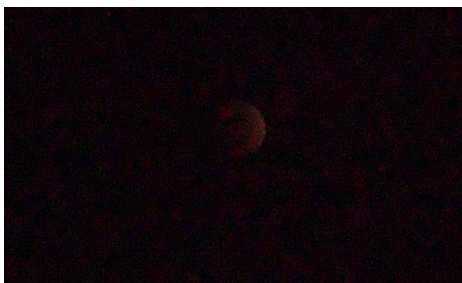
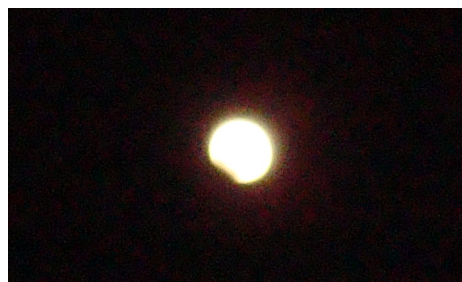
only when something powers that motion, and he viewed his system of the sun, moon, and stars as being a kind of mechanical device powered by an external source that lay beyond the stars -- a source he called the *Prime Mover*. Here Aristotle retained a link to the supernatural, for he linked the Prime Mover to the action of a single, supreme, unchanging God that Aristotle reasoned must exist. Being unchanging, this God did not need people to keep it (Aristotle's God was not a person) happy, and could be relied on to make the sun rise and set for all time.

Aristotle's ideas really make a lot of sense (if we forget for a moment that some of them are “wrong”). Let's start with the Earth being round. How did Aristotle know that? Actually, other thinkers besides Aristotle knew the Earth was round. It really isn't that hard to see for yourself that Earth is round. For example, if you have ever seen an eclipse of the moon (when the full moon passes through Earth's shadow), then when you watched the eclipse you probably noticed that the Earth's shadow is round. That would indicate that the Earth is round -- round objects cast round shadows.

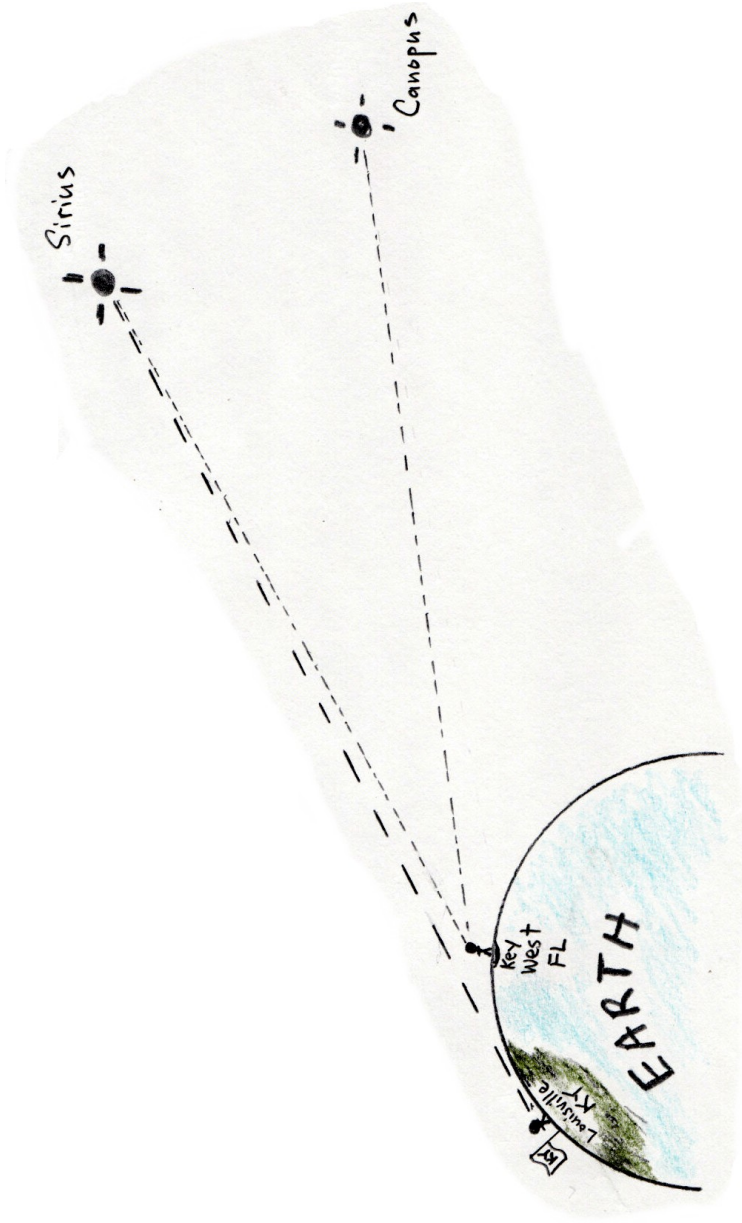
As another example, if you travel south, stars appear above the horizon that are not visible further north. In the winter skies of Louisville, Kentucky, the star Sirius reigns unchallenged. It is the brightest star visible in the night sky. But a “snowbird” who travels from Louisville to Key West Florida will see a distinct change in the night sky. As seen from Key West, Sirius has a challenger, the brilliant star Canopus, visible just below Sirius. It is the fact that the snowbird is moving around the curve of the Earth that causes new stars to appear during travel to the south. If the Earth were flat then everyone everywhere would basically see the same stars (refer to the diagram following the next page). The Greeks of Aristotle's day did not travel between Kentucky and Florida, but they traveled enough to notice this phenomenon. You actually can see changes in the stars by traveling just a couple of hundred miles north or south.

Now let's consider Aristotle's ideas about what the Earth and the heavens are made of, because they make sense, too. Aristotle believed the things on Earth are made of four elements -- earth, water, air, and fire -- much like what we saw in our explanation of the falling bolt and paper. He thought that the natural tendency of things on Earth is to move in straight line paths until they reach their natural positions. So fire rises straight up in still air because of its levity, and a rock falls straight to the ground if dropped because of its gravity. And in general, things tend toward a state of rest, moving only if they are being

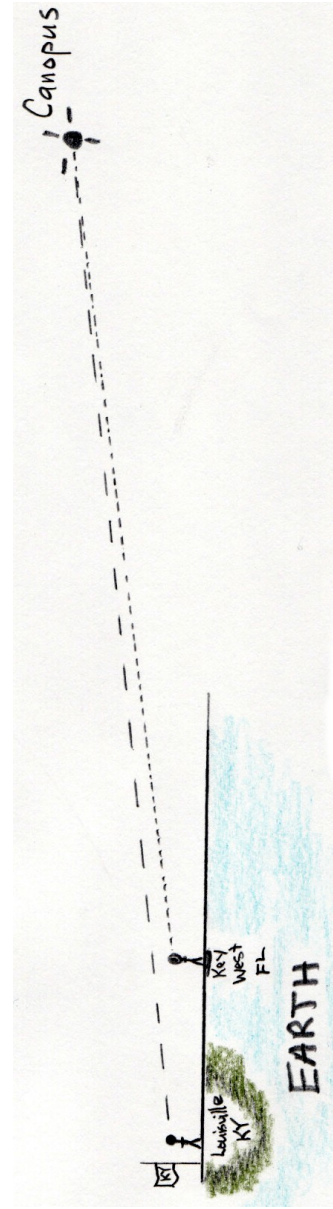
The full moon starting to pass into Earth's shadow during an eclipse of the moon. The shadow is round, indicating that the object that is casting the shadow (the Earth) is also round. Left – photograph by Bill Ogg Photography. Right – sequence of photographs taken by Jefferson Community & Technical College student Tammy Duncan (February 2008), showing the progression of Earth's shadow across the moon over time. The features on the lunar surface are washed out in these photographs.



When in Kentucky, a traveler can see Sirius, but she can not see Canopus because the Earth blocks her line of sight. When she is in Key West, Florida, however, she can see both Sirius and Canopus.



If the Earth were flat, then the traveler could see Canopus from both Kentucky and Florida.



powered by some kind of “mover”. If you push a wagon it will move, but once you stop pushing, the wagon quickly comes to rest. The harder you push the wagon, the faster it moves.

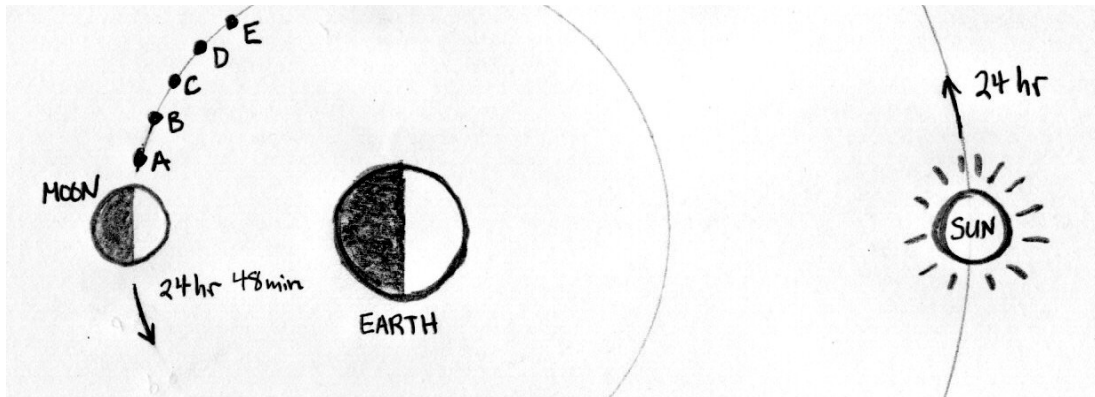
By contrast, Aristotle thought the heavens have to be made of something unlike anything on Earth. As we mentioned in Chapter 3, the constancy of the heavens' cycles is something that is unlike anything in human experience. Change is a part of life on Earth, but the heavens are apparently changeless, going through their cycles endlessly. So Aristotle supposed that the heavens are composed of a “Fifth Element” that was unlike the Earthly four. Thus the sun and the moon never go dark, the mechanism that governs their motion around the Earth never wears out, and the Prime Mover that powers their motion never tires out.

Dear Reader, do you think it is odd that Aristotle simply created this “Fifth Element”, with its special properties not found on Earth, in order to explain the appearance of the heavens? If so, do you know that astronomers *today* say that much of the universe consists of “dark matter” and “dark energy”? Do you know that “dark matter” and “dark energy” are entities that are not observable on Earth, that have special properties that explain the appearance of the universe (the heavens)? Aristotle's thinking was not so odd -- modern astronomers do the same kind of thing! (But keep in mind that while dark matter and dark energy may be the same *kind* of idea as the Fifth Element, modern astronomers have a very different view of the universe than Aristotle did.)

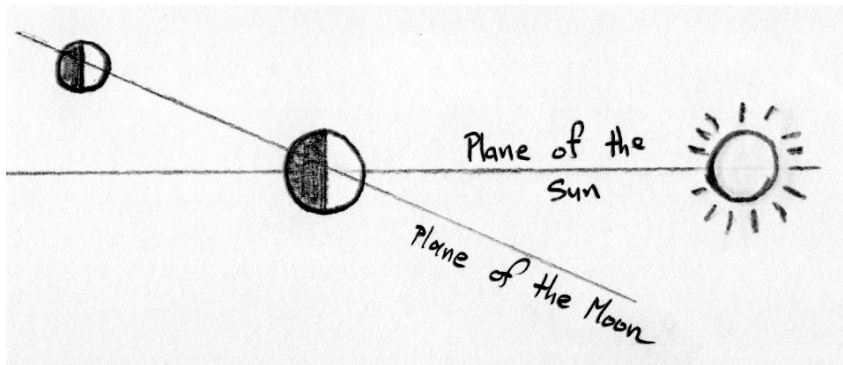
Aristotle's view of how the universe functions is a marvelous theory that combines scientific insight and common sense. It gets rid of most of the supernatural stuff that leads to magic, and to worrying about whether the sun will rise tomorrow if the gods are unhappy (the Prime Mover remains a bit supernatural). It boils a lot of phenomena down to a few basic principles that are based on the substances things are made of and how those substances tend to move. And it can explain plenty of things.

For example, the cycle of the moon is easily understood using Aristotle's ideas. Imagine that the sun, the Earth, and the moon all lie in a line, as shown in the top diagram on the next page. The sun illuminates both the moon and the Earth; this means their sides that face toward the sun are lighted and their sides that face away from the sun are dark. A person on the night (dark) side of Earth cannot see the dark side of the moon -- only the lit side. So, the moon will appear fully lit. It will be a “Full Moon”.

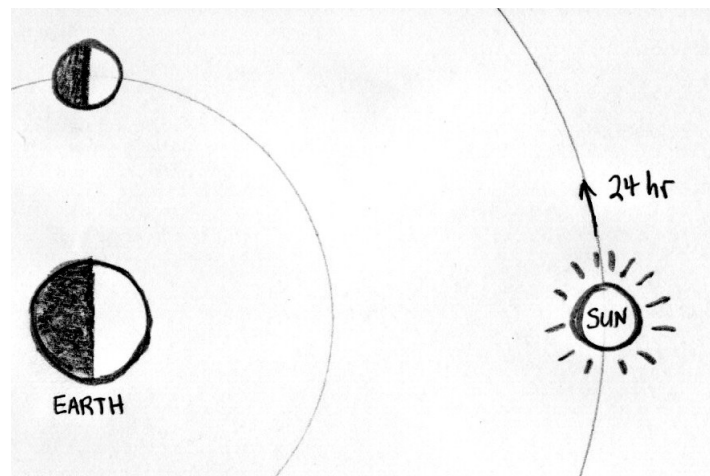




Alignment of sun, Earth, and moon at Full Moon. Often people wonder why the Earth would not block the light from the sun when they are in this alignment. The answer is that while Aristotle has both sun and moon circling the Earth, they need not circle in the exact same plane. The moon's orbit travels above and below the plane of the sun's orbit as shown below, which shows a "side view" of the orbits. So the moon lies in line with the Earth and sun when viewed from above, but when viewed from the side it is not in line – it is above the Earth's shadow.



Now we wait 24 hours -- one day. The sun will circle completely around the Earth, and end up right back where it started. The moon is slower, however. It takes 24 hours, 48 minutes to completely circle the Earth. So after 24 hours it will not have completed a full circle, and will be at point "A" in the diagram on the previous page. We wait another 24 hours -- a second day. The sun circles the Earth completely, but again the moon comes up a little short, and ends up at point "B" in the diagram. After a third day the moon is at "C" in the diagram, after a fourth it is at "D", and so forth. The moon is losing 48 minutes each day against the sun, so after 7.5 days it will have lost 6 hours³ against the sun. Six hours is one *quarter* of 24 hours, the sun's cycle. So after 7.5 days the moon will be positioned as shown below, one *quarter* of a circle off the original alignment it had with the sun and Earth.



At this position a person on the night (dark) side of Earth can see the dark and lighted sides of the moon equally. So, the moon will appear half lit -- the moon is a "Quarter Moon". In another 7.5 days the moon will lie between the Earth and the sun and only the dark side will face Earth. That, and the fact that the moon will be near to the sun in the sky, will make the moon invisible. This is what we call a "New Moon". 7.5 days more will take us to another "Quarter Moon"; 7.5 days after that gets us back to a Full Moon. Thus Full Moon to Full Moon is 30 days; New Moon to New Moon



3 48 minutes/day x 7.5 days = 360 minutes. 360 minutes ÷ 60 min/hr = 6 hours.

is 30 days. Usually the lunar cycle is presented as beginning with the New Moon, as shown here:



Note that the Full Moon is half-way through the Lunar cycle -- it could be called “Second Quarter”! An exercise similar to this one can be performed with the stars to show that Aristotle’s ideas can explain the yearly changes in the stars, too.

There we have it. Aristotle’s theory of the universe explains everything we have observed – the rising and setting of the sun, moon, and stars; the monthly and yearly cycles of the heavens; the unchanging nature of the heavens; and more. It is almost perfect. (In fact, Aristotle’s explanation of the workings of the universe is so neat, and makes so much sense, that we should probably stop for a moment and remind ourselves that Aristotle was *wrong*: No, the sun does *not* circle the Earth, and neither do the stars; the moon does circle the Earth, but it does not do so every 24 hours, 48 minutes.)

There is, however, a heavenly phenomenon that Aristotle’s theory does not explain so perfectly. Until now we have left out something in our discussion of what we can see in the heavens. Now it is time to discuss that something.