MODULE #1: A Brief History of Science

Introduction

This course will take you on a tour of what I consider to be the most interesting of all human endeavors: **science**. Now, of course, I am well aware that many people (perhaps even you) do not think science is interesting. Nevertheless, I do believe that most people's dislike of science comes from bad curriculum and/or bad teachers, not the subject itself. Hopefully, as you go through this course, you will see why I find science so incredibly interesting, and if nothing else, you will at least develop an appreciation for this fascinating field of study.

So what is science, anyway? Well, the word "science" comes from the Latin word "scientia" (sye en' tee uh), which means "to have knowledge." It can be generally defined as follows:

Science – An endeavor dedicated to the accumulation and classification of observable facts in order to formulate general laws about the natural world

That's a nice definition, but what does it mean? It means that the *purpose* of science is to develop general laws that explain how the world around us works and why things happen the way they do. How do we accomplish such a feat? That's where the "accumulation and classification of observable facts" comes in. The *practice* of science involves experimentation and observation. Scientists observe the world around them and collect facts. They also design experiments that alter the circumstances they are observing, which in turn leads to the collection of more facts. These facts might eventually allow scientists to learn enough about the world around them so they can develop ideas that help us understand how the natural world works.

As is the case with any other field, the only way to truly understand where we are in science today is to look at what happened in the past. The history of science can teach us many lessons about how science should and should not be practiced. It can also help us understand the direction in which science is heading today. In the end, then, no one should undertake a serious study of science without first taking a look at its history. That's where we will start in the course. This module will provide you with a brief history of human scientific inquiry. If you do not like history, please stick with this module. You will start to sink your teeth into science in the next module. Without a historical perspective, however, you will not fully appreciate what science is.

The First Inklings of Science (From Ancient Times to 600 B.C.)

Some of the earliest records from history indicate that 3,000 years before Christ, the ancient Egyptians already had reasonably sophisticated medical practices. Sometime around 2650 B.C., for example, a man named **Imhotep** (eem' oh tep) was renowned for his knowledge of medicine. People traveled from all over the Middle East to visit Imhotep, hoping he would cure their illnesses.

Most historians agree that the heart of Egyptian medicine was trial and error. Egyptian doctors would try one remedy, and if it worked, they would continue to use it. If a remedy they tried didn't work, the patient might die, but at least the doctors learned that next time they should try a different remedy. Despite the fact that such practices sound primitive, the results were, sometimes, surprisingly effective. For example, Egyptian doctors learned that if you covered an open wound with moldy bread, the wound would heal quickly and cleanly. As a result, most Egyptian doctors applied moldy bread to their patients' wounds. Modern science tells us that certain bread molds produce **penicillin**, a chemical that kills germs that infect wounds! Thus, even though the Egyptian doctors knew *nothing* about germs, they were able to treat wounds in a way that helped avoid infections!

Another example of the surprisingly effective art of ancient Egyptian medicine can be seen in the way they treated pain. In order to relieve a patient who was in pain, Egyptian doctors would feed the patient seeds from a flowering plant called the **poppy**. Eating these **poppy seeds** seemed to relieve the patient's pain. Modern science tells us *why* this worked. Poppy seeds contain both **morphine** and **codeine**, which are excellent pain-relieving drugs still used today!

FIGURE 1.1
Natural Remedies Used By Ancient Egyptians

Since some bread molds produce germ-fighting chemicals, they can aid in healing wounds.

Poppy seeds (and other parts of the plant) contain chemicals that help relieve pain.

Why was Egyptian medicine advanced compared to the medicine of other ancient nations? Well, at least one reason was the Egyptian invention of **papyrus** (puh pye' rus).

<u>Papyrus</u> – An ancient form of paper, made from a plant of the same name

As early as 3,000 years before Christ, Egyptians took thin slices of the stem of the papyrus plant, laid them crosswise on top of each other, moistened them, and then pressed and dried them. The result was a form of paper that was reasonably easy to write on and store.

The invention of this ancient form of paper revolutionized the way information was transmitted from person to person and generation to generation. Before papyrus, Egyptians, Sumerians, and other races wrote on clay tablets or smooth rocks. This was a time-consuming process, and the products were not easy to store or transport. When Egyptians began writing on papyrus, all of that changed.

Papyrus was easy to roll into scrolls. Thus, Egyptian writings became easy to store and transport. As a result, the knowledge of one scholar could be easily transferred to other scholars. As this accumulated knowledge was passed down from generation to generation, Egyptian medicine became the most respected form of medicine in the known world!

Although the Egyptians were renowned for their medicine and for papyrus, other cultures had impressive inventions of their own. Around the time that papyrus was first being used in Egypt, the Mesopotamians were making pottery using the first known potter's wheel. Not long after, horse-drawn chariots were being used. As early as 1,000 years before Christ, the Chinese were using compasses to aid themselves in their travels. The ancient world, then, was filled with inventions that, although they sound commonplace today, revolutionized life during those times. These inventions are history's first inklings of science.

As you progress through this course, you will see that it is divided into sections. Usually, at the end of each section, you will find one or two "On Your Own" questions. You should answer these questions as soon as you come to them in the reading. They are designed to make you think about what you have just read. These questions are often not very easy to answer, because you cannot simply look back over the reading and find the answer. You must *think* about what you have learned and make some conclusions in order to answer the question. You will find your first such question below. Answer it on a separate sheet of paper and then check your answer against the solution provided at the end of this module.

ON YOUR OWN

1.1 Although the ancient Egyptians had reasonably advanced medical practices for their times, and although there were many inventions that revolutionized life in the ancient world, most historians of science do not think of Egyptian doctors and ancient inventors as scientists. Why? (Hint: Look at the entire definition of science.)

True Science Begins to Emerge (600 B.C. to 500 A.D.)

As far as historians can tell, the first true scientists were the ancient Greeks. Remember, science consists of collecting facts and observations and then using those observations to explain the natural world. Although many cultures like the ancient Egyptians, Mesopotamians, and Chinese had collected observations and facts, they had not tried to use those facts to develop explanations of the world around them. As near as historians can tell, that didn't happen until the 6th century B.C., with three individuals known as **Thales**, **Anaximander** (an axe' uh man der), and **Anaximenes** (an axe' uh me' neez). Many historians view these three individuals as humanity's first real scientists.

Thales studied the heavens and tried to develop a unifying theme that would explain the movement of the heavenly bodies (the planets and stars). He was at least partially successful, as history tells us he used his ideas to predict certain planetary events. For example, he gained a great reputation throughout the known world when he correctly predicted the "short-term disappearance of the sun." What he predicted, of course, was a solar eclipse, an event in which the moon moves between the earth and the sun, mostly blocking the sun from view.

Anaximander was probably a pupil of Thales. He was much more interested in the study of life, however. As far as we know, he was the first scientist who tried to explain the origin of the human race without reference to a creator. He believed that all life began in the sea, and at one time, humans were actually some sort of fish. This idea was later resurrected by other scientists, most notably Charles Darwin, and is today called evolution. Later on in this course, I will discuss evolution, showing how the data we currently have do not support it.

Anaximenes was probably an associate of Anaximander. He believed that air was the most basic substance in nature. In fact, he believed all things were constructed of air. When air is thinned out, he thought, it grows warm and becomes fire. When air is thickened, he thought, it condenses into liquid and solid matter. We know, of course, that these ideas are wrong. Nevertheless, his attempts to explain all things in nature as being made of a single substance led to one of the most important scientific ideas introduced by the Greeks: the concept of **atoms**.

Leucippus (loo sip' us) was a Greek scientist who lived perhaps 100 to 150 years after Anaximenes. Although little is known about him, historians believe that he built on the concepts of Anaximenes and proposed that all matter is composed of little units called "atoms." As a result, Leucippus is known as the father of atomic theory. The works of his student **Democritus** (duh mah' crit us) are much better preserved.

Democritus used the following illustration to communicate his ideas about atoms: Think about walking towards a sandy beach. When you are a long way from the beach, the sand looks like a smooth, yellow blanket. As you get closer to the beach, you might notice that there are bumps and valleys in the sand, but the sand still looks solid. When you reach the beach and actually kneel down and examine the sand, you find that it is not solid at all. Instead, it is composed of tiny particles called "grains."

Democritus believed that all matter was similar to sand. Even though a piece of wood appears to be solid, it is, in fact, made up of little individual particles that Democritus and his teacher called atoms. Perform the following experiment to see the kind of observation best explained using the concept of atoms.

EXPERIMENT 1.1

Density in Nature

<u>Supplies</u>

- Vegetable oil
- Water
- Maple or corn syrup
- A grape
- A piece of cork
- An ice cube
- A small rock
- A tall glass
- Eye protection such as goggles or safety glasses

Introduction: Observations such as the ones you will make in this experiment are easy to explain when you assume the existence of atoms.

Procedure:

1. Take the glass and fill it about ¼ of the way with the vegetable oil.
2. Add an equal amount of water to the glass.
3. Add an equal amount of maple syrup to the glass.
4. Now look at the glass from the side. What do you see? In your laboratory notebook, make a sketch of what you see.
5. Drop the rock, the grape, the ice cube, and the piece of cork into the glass. Now what do you see? Add the rock, grape, ice cube, and cork to the sketch you made in step 4.
6. Clean up your mess and put everything away.

What did you see in the experiment? If everything went well, you should have seen that the liquids formed layers in the glass. The vegetable oil formed a layer on top, the water layer was in the middle, and the syrup layer was at the bottom. In addition, the cork should have floated on top of the vegetable oil; the ice cube should have floated on top of the water layer; the grape should have floated on top of the syrup layer, and the rock should have sunk to the bottom of the glass.

How in the world is this experiment evidence for the existence of atoms? Well, according to Democritus, the water, vegetable oil, and syrup are all made of individual particles called atoms. The way those atoms are packed together will determine each object's characteristics. For example, assuming that the atoms in water are packed more closely than those in vegetable oil, the water will be able to pass between the atoms in the vegetable oil, sinking to the bottom of the glass. In the same way, the atoms in the syrup are more tightly packed than those in water or vegetable oil, so the syrup's atoms were able to fall in between the atoms of both the vegetable oil and the water to land at the bottom of the glass.

Even solid objects are made up of atoms. Thus, the cork's atoms are packed together very loosely. As a result, the cork doesn't have much weight and cannot push its way through the atoms in the vegetable oil. That's why it floats on top of the vegetable oil. The atoms in the ice cube, however, are more tightly packed and make the ice cube heavy enough to push the atoms in vegetable oil out of the way. This allows it to sink through the vegetable oil. However, they are not tightly packed enough to allow the ice cube to push through the atoms in the water.

If substances were not composed of smaller particles (like atoms), it would be hard to understand how one substance could pass through another substance. However, if you imagine every substance to be made up of little grains (like sand), then passing through a substance would just be a matter of fitting between the grains or pushing the grains out of the way. Thus, if you assume the existence of atoms, results of experiments like the one you just did are easy to understand.

At this point, I am done discussing the experiment. Now that you know what the experiment shows, you can write a summary of it in your laboratory notebook. Write a brief description of what you did, followed by a discussion of what you learned. The goal you should have in mind is that someone who has never read this book should be able to read your laboratory notebook and understand what you did and what you learned. You should do this for *every* experiment.

Democritus was not well received in his time, but later scientists picked up on his ideas and refined them. Today, we know that all matter is made up of atoms. Indeed, today we can actually calculate how atoms pack together to make a given substance. This allows us to understand the concept of **density**, which describes how tightly packed the matter in a substance is. The more tightly packed the matter that makes up a substance, the higher its density. In your experiment, then, the syrup had a higher density than the water.

FIGURE 1.2
Democritus

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We don't really know what Democritus looked like, but this is how Dutch painter Hendrick ter Brugghen imagined him. He was called the "Laughing Philosopher," but no one is exactly sure why. Some suggest it is because he considered cheerfulness to be an important goal in life. Others suggest it is because he was prone to laugh when he thought someone else was making a stupid mistake.

Although Democritus was right about all things being composed of atoms, he was wrong about most of the details regarding what atoms are really like. He believed, for example, that atoms are indestructible. We now know that is wrong. After all, the atomic bomb and nuclear energy are both based on our ability to split atoms. He also thought that atoms were distinguished based on their shape and size. We now know it is a *lot* more complicated than that.

While Democritus was wrong on many of the details related to atoms, there was one detail he got right. He thought that atoms were in constant motion. For example, if a glass of water is sitting on a table, you might think the water is not in motion. To some extent, you would be right. After all, the water in the glass stays in the glass, and the glass itself stays on the table. At the same time, however, the atoms that make up the water are in *constant* motion. They move around within the confines of the glass, rebounding off the walls of the glass and colliding into each other. You might find it hard to believe that the atoms within a glass of water are in motion when the water itself is not. However, you might find it a little easier to believe after performing the following experiment.

EXPERIMENT 1.2
Atomic Motion

Supplies:

- Two glass canning jars or peanut butter jars (both the same size)
- Food coloring (any color)
- A pan and stove to boil water, and a hotpad to hold the pan
- Eye protection such as goggles or safety glasses

Introduction: By seeing how food coloring gets distributed through two jars of water at different temperatures, you will collect evidence for the fact that atoms are in constant motion.

Procedure:

1. Boil some water. You need to boil enough to fill one of the jars about halfway.
2. Once the water is boiling, take it off the stove (use the hotpad!) and pour it into one of the jars. Pour in enough water so that the jar is about half full.
3. Fill the other jar about halfway with cold water from the tap.
4. Wait until the water in each jar is still.
5. Drop a single drop of food coloring into each jar. Observe what happens over the next several minutes. Record in your laboratory notebook the difference between what happened in each jar.
6. **OPTIONAL**: Let the jar with the cold water sit out for a full day. Record what the jar looks like afterward.
7. Clean up your mess.

What did you see in the experiment? If everything went well, you should have seen the drop of food coloring mix rapidly with the hot water, coloring the entire jar of water relatively quickly. In the jar of cold water, however, the food coloring should not have mixed well at all. Why was there a difference? The answer is found in the motion of atoms. When a substance is hot, its atoms move faster than when it is cold. When you added food coloring to the cold water, then, the atoms in the water collided with the atoms in the food coloring, moving them around. However, since the atoms in the cold water were not moving very quickly, the food coloring did not get moved around much, so it did not mix well with the water. Given enough time, the food coloring will mix well with the water, eventually becoming evenly distributed throughout the jar. When you added the food coloring to the hot water, however, the collisions between the atoms in the food coloring and the atoms in the water were much more violent, because the atoms in the water were moving much more quickly. This moved the atoms in the food coloring around quite a bit, spreading them out evenly throughout the jar of water in a short amount of time.

In the end, then, even though Democritus was wrong about a great many things, he was right about two important ideas. First, all things are, indeed, composed of atoms. Second, those atoms are in constant motion. Now as I said before, Democritus was not well received in his time. Most of his fellow scientists rejected his ideas. In fact, the whole idea of the existence of atoms did not gain much popular support among scientists for almost 2,000 years! This just goes to show you that scientists do not always recognize a good idea when they see one. In fact, the history of science is filled with instances of scientists rejecting good ideas in favor of bad ones. You will see more examples of that as you work through the rest of this course.

ON YOUR OWN

1.2 Based on your results in Experiment 1.1, order the items you used in your experiment (water, vegetable oil, the grape, etc.) in terms of increasing density. In other words, list the item with the lowest density first, followed by items of higher and higher density, and end your list with the item of greatest density.

1.3 Do the atoms in an ice cube move faster or slower than the atoms in a glass of water?

Three Other Notable Greek Scientists

Ancient Greece gave us many more notable scientists. It is impossible to discuss them all in a single chapter, but there are three more that simply must be mentioned. The first is **Aristotle**, often called the father of the life sciences. Aristotle was born shortly before Democritus died. He wrote volumes of works on many things, including philosophy, mathematics, logic, and physics. His greatest work, however, was in the study of living things. He was the first to make a large-scale attempt at the **classification** of animals and plants.

What is classification? It is a lot like filing papers. Remember, science is a two-part process. A scientist must gather facts and then use those facts to draw conclusions about how the natural world works. As you gather more and more facts, they tend to get hard to use unless they can be ordered in some reasonable, systematic way. That's what classification is all about. By the time of Aristotle, Greek scientists had catalogued many plants and animals, but there were so many that keeping track of them was proving to be very difficult. Aristotle came up with a classification scheme that allowed him to group the known plants and animals into an easy-to-reference system. Because Aristotle was financially supported by **Alexander the Great** (you should have read about him in your history books), he was able to obtain plant and animal samples from all over the known world, adding those to his classification scheme.

Although we do not use Aristotle's particular classification scheme today, all fields of science are still committed to the concept of classification. Indeed, scientists who study living things today are still wrestling with producing the ideal classification system for understanding the life sciences. In a future module of this course, you will get a brief introduction to biological classification. You will then see a *lot* more of it when you reach biology in high school.

Although Aristotle was known for a great number of wonderful advances in the sciences, he was also responsible for a great deal of nonsense that hampered science for many, many years. For example, he believed that certain living organisms spontaneously formed from non-living substances. This idea was called **spontaneous generation**.

Spontaneous generation – The idea that living organisms can be spontaneously formed from non-living substances

This idea led scientists to think, for example, that maggots (young flies) spontaneously formed from rotting meat. In other words, if you put rotting meat out, it would simply turn into maggots within a few days.

Of course, we now know that spontaneous generation is impossible. In all our experience, life can only be formed by the reproduction of other living things. People have children, animals produce offspring, and plants make seeds that grow into new plants. These are some of the ways life is formed. Life simply cannot be formed from non-living things. You will learn a lot more of the details regarding the story of spontaneous generation when you take biology. For right now, however, I want to make a point about how science should *not* be done, and spontaneous generation is an excellent example to use in order to make this point.

You see, all great scientists make mistakes. Democritus was thousands of years ahead of his time in proposing the existence of atoms, but he was wrong about most of the details regarding atoms.

Aristotle made great advances in the study of living things, but he believed in spontaneous generation. Aristotle's mistake was much more damaging to the advancement of science than was Democritus's mistakes, however. Why? Because Aristotle was *so well-respected!* You see, Aristotle was considered (rightly so) one of the greatest scientists of his time. Thus, his ideas (even the wrong ones) were revered for *generations!* In fact, the absurd notion of spontaneous generation lasted *well into the 1800s*, more than *2,000 years after* it was proposed by Aristotle.

FIGURE 1.3
Aristotle

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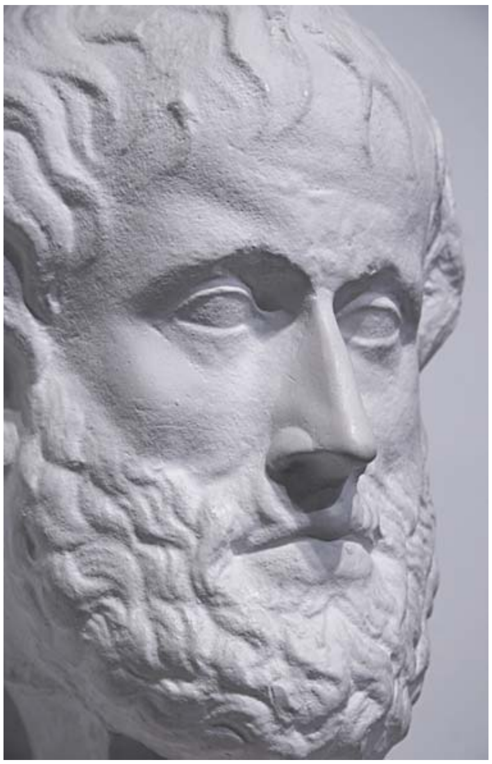


This is a sculpture that was made to honor Aristotle. He was rightly considered one of the greatest scientists in his day, but unfortunately, that hurt science in the long run. The idea of spontaneous generation, for example, lasted for a long, long time because Aristotle championed it. Scientists thought that since Aristotle was such a great scientist, he couldn't possibly be wrong about something so important. Thus, they continued to believe in spontaneous generation despite the evidence against it. In other words, *the reputation of Aristotle*, not scientific evidence, was the reason people believed in the idea. As a result, it took more than 2,000 years for science to show the fallacy of spontaneous generation. This is a great example of how science should *not* be done. Every scientist, no matter how great, will make mistakes. **Thus, no scientist's work should be supported because the *scientist* was great. It should only be supported because the *scientific evidence* supports it!** Sadly, this lesson has not been learned by many of today's scientists! Wrong-headed ideas still survive in science simply because they are championed by respected scientists.

The next Greek scientist worthy of note was **Archimedes** (ark uh me' deez), who lived roughly 100 years after Aristotle. He did great work in mathematics, and he used much of what he discovered in math to advance science. He applied mathematical formulas to explain why certain things happened the way they did. Archimedes was really one of the first scientists to demonstrate how closely mathematics and science are linked.

Archimedes is probably best known for his work with fluids. He was the first to show how you could predict whether or not an object would float in a liquid. His work with liquids led to one of the more entertaining stories in the history of science. The king that Archimedes served, King Hiero, once asked Archimedes to analyze a crown that was made for him. The crown was supposed to be made of gold, but the king was skeptical. Archimedes knew how to determine whether or not the crown was made of gold, but the process required him to know the exact amount of space the crown occupied. This seemed impossible, as the crown was so irregularly shaped that Archimedes could not find a way to measure it accurately.

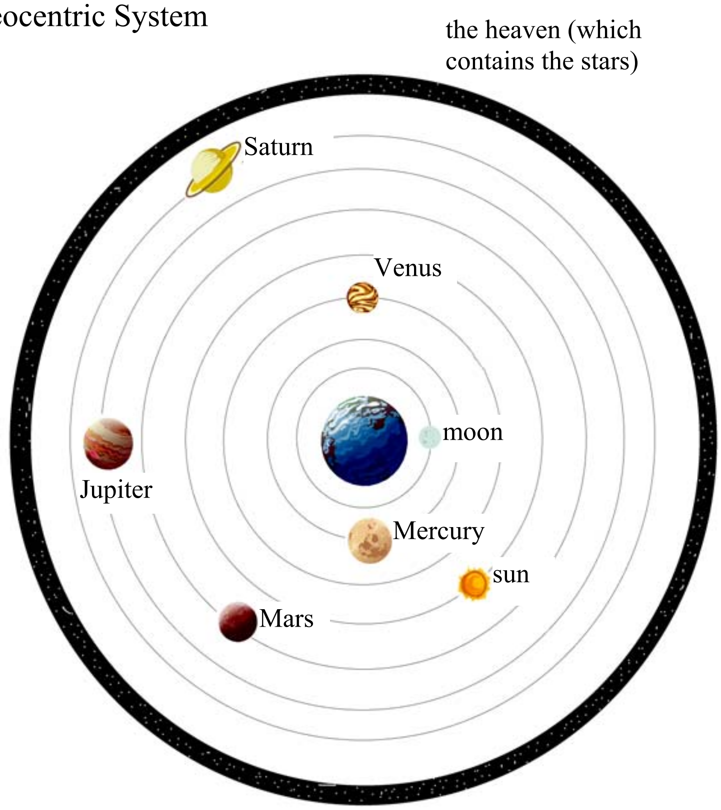
Well, one day while taking a bath, Archimedes realized that when an item is immersed in water, it displaces the same amount of water as the space that the item occupies in the water. Thus, all

Archimedes had to do was immerse the crown in water and determine how much water it displaced. That would tell him how much space the crown occupied. Archimedes was so excited by this discovery that he ran through the streets screaming "Eureka," which means "I have found it." There was one embarrassing little problem, however. Archimedes was so excited by his discovery that he *forgot to put any clothes on!* In other words, he ran through the streets *completely naked!* While Archimedes himself never wrote of this incident (I would think he was too embarrassed), the story was reported by a Roman writer named Vitruvius about 200 years after it was supposed to have happened.

The last Greek scientist I want to discuss lived about 100 years after Christ's birth. His name was **Ptolemy** (tahl' uh mee), and he studied the heavens. He was one of the first to attempt a complete description of the planets and stars. He assumed that the earth was at the center of the universe, and that the planets and stars orbited about the earth in a series of circles.

FIGURE 1.4
The Geocentric System

In the geocentric system, the earth sits at the center of the universe and does not move. The planets travel around the earth in circles within circles. What this means is that the "average" path of each planet around the earth is given by the gray lines in the figure. However, the planets themselves do not travel directly along those lines. Instead, they travel in little circles (called epicycles) centered on those lines. This makes each planet's path more of a spiral, the center of which is marked by the gray lines. The moon is closest to the earth, followed by Mercury, Venus, the sun, Mars, Jupiter, and Saturn. Those were the only planets known in Ptolemy's day. The stars are contained in a canopy called "the heaven." Although the stars are fixed in the heaven, the heaven rotates, which makes the stars themselves appear to move.



At the time, Ptolemy could explain a lot of the astronomical data that had been collected using his idea, so it became very popular. Sometimes, his view of the stars and planets is referred to as the **Ptolemaic system**, in an attempt to honor him. Sometimes, it is referred to as the **geocentric system**, to emphasize the fact that Ptolemy thought the earth was at the center of the universe.

The geocentric system was considered the correct explanation for the arrangement of planets and stars in space until about the 1700s. Thus, it was a popular theory for nearly 1,600 years. Once again, however, the reason the geocentric system was so popular had less to do with the scientific evidence and more to do with other considerations. Like Aristotle, Ptolemy was (rightly) considered a great scientist. As data were collected that contradicted the geocentric system, many scientists ignored the data out of reverence for Ptolemy.

There was actually another, probably more important reason the geocentric system became so popular: It fit many scientists' preconceived notions of how things ought to be. In the geocentric system, the earth was at the center of the universe and everything revolved around it. Since most people believed that the earth was the most important part of the universe, the geocentric system "made sense."

Sadly, some of the most ardent support for the geocentric system came from the Roman Catholic Church. As more and more scientific evidence came pouring in indicating severe flaws in the geocentric system, the church tried to resist any movement away from it. After all, the church reasoned, since God created man, the earth must be the most important thing in the universe, so it must be at the very center, and everything else must travel around it, just as Ptolemy said. Now, of course, nowhere in the Bible is such a thing written, but that didn't stop the church from believing in it!

In the end, it took hundreds of years of scientific data (and a few people being thrown out of the Roman Catholic Church) before the church was convinced to give up on the geocentric system. Unfortunately, by that time, the damage had been done. The church became viewed as antagonistic towards science, and some people today still hold that view. This is unfortunate because, as you will see in later sections of this module, Christianity is a friend to science. Most of the great scientists in history were Christians, and their Christianity is often credited for their scientific achievements. Nevertheless, because the Roman Catholic Church was unwilling to give up on the geocentric system when the scientific evidence was overwhelming, many still see Christianity as an enemy of science. That's too bad.

So this little episode from history shows us another way that science should *not* be done. You should not hold fast to an idea simply because it fits with your preconceived notions. Science is built on data, not a person's beliefs. The acceptance or rejection of a scientific proposition, then, should rest solely on the data, nothing more. Today, there is an idea called **evolution**. It is popular among scientists not because there is a lot of evidence for it, but because it fits many scientists' preconceived notions. As you will learn in a later module, very little evidence exists for the idea of evolution, and significant evidence exists against it. Nevertheless, it is still a prevalent idea because many people like the fact that it tries to explain the existence of life without ever referring to God. As a result, they believe the idea in spite of the evidence. Unfortunately, these people have not learned from the history of science. The history of science teaches us over and over again that believing in an idea because of preconceived notions hurts the cause of science; it does not help it!

ON YOUR OWN

1.4 Dr. Steven Hawking is one of the most brilliant scientists of the decade. He believes in an idea called "the big bang." This idea tries to describe how the universe was formed. If your friend tells you that you should believe in the big bang because Dr. Hawking is smart and he believes in it, what famous example from the history of science should you tell to your friend?

1.5 What episode from the history of science tells us we need to leave our personal biases behind when we do science?

The Progress of Science Stalls for a While (500 A.D. to 1000 A.D.)

From the time of the first three Greek scientists (Thales, Anaximander, and Anaximenes) until about 400 or 500 A.D., science progressed at a steady rate. Many scientists proposed many ideas trying to explain the natural world. Those ideas were debated and refined. Great houses of learning were established to foster scientific inquiry. Works like those of Aristotle and Ptolemy became the guiding principles behind the progress of science.

After the first few centuries A.D., however, the progress of science stalled dramatically. By that time, the Roman Empire had a great deal of influence throughout the known world, and Rome had a distinct dislike of science. The Roman Empire did not mind inventions, especially those that made work more productive, but it had little use for the practice of explaining the world around us. As a result, real science was actively discouraged in most parts of the world.

Alchemy (al' kuh mee) is one of the best examples of what passed for science during this time period. Alchemists mostly wanted to find a means by which lead (or some other inexpensive substance) could be transformed into gold (or some other precious substance). You see, many people had observed the fact that when you mix certain substances together, they change into other substances. Perform the following experiment to see what I mean.

EXPERIMENT 1.3
A Chemical Reaction

Supplies:

- A clear plastic 2-liter bottle
- A balloon (6-inch to 9-inch round balloons work best.)
- Clear vinegar
- Baking soda
- A funnel or butter knife
- A few leaves of red (sometimes called purple) cabbage
- A saucepan
- A stove
- Measuring cups
- A few ice cubes
- Eye protection such as goggles or safety glasses

Introduction: Mixing specific substances together can produce amazing results. This experiment shows you some of what can happen when the right substances are mixed together.

Procedure:

1. Put about 2 cups of water in the saucepan and add several leaves of red cabbage. Put it on a stove burner and heat it so the water boils.
2. While you are waiting for the water to boil, put about 2 tablespoons of baking soda into the balloon. The best way to do this, of course, is to use a funnel. If you do not have a funnel, try picking up the baking soda on the flat end of a butter knife, pushing the knife into the balloon's opening, and then tipping the knife so the baking soda spills into the balloon. It is a tedious process, but you will eventually get all the baking soda you need into the balloon.

3. Once the balloon has about 2 tablespoons of baking soda in it, pour ¾ cup of clear vinegar into the 2-liter bottle.
4. Once the water in the saucepan starts boiling, remove it from the heat. Allow the liquid in the pan to cool by adding some ice. The liquid should have a blue or pink color now.
5. Add ½ cup of the liquid to the 2-liter bottle.
6. Attach the balloon to the opening of the 2-liter bottle by stretching the balloon's opening over the lip of the bottle. In the end, your experiment should look like this:

7. Once you are ready, lift the balloon so the baking soda falls into the vinegar. Write down what you see in your laboratory notebook.
8. Clean up your mess and put everything away.

What did you see in the experiment? When the baking soda hit the vinegar, the mixture should have bubbled and fizzed, and the balloon should have inflated. At the same time, you should have noticed a color change. The mixture should have turned from a pinkish color to a bluish color. What happened? Well, you witnessed the effect of a **chemical reaction**. In a chemical reaction, one or more substances interact to form one or more new substances.

In your experiment, there were actually two chemical reactions going on. The first occurred when vinegar was mixed with baking soda. Those two substances interacted, forming three new substances: carbon dioxide, sodium acetate, and water. The carbon dioxide, which is a gas, bubbled out of the vinegar and into the balloon, filling up the balloon. The second reaction occurred as the vinegar was being used up in the first reaction. A substance in red cabbage, anthocyanin (an thuh sye' uh nun), interacted with the vinegar to form a pink color. As the vinegar was transformed into new substances by the first reaction, the anthocyanin no longer had vinegar to interact with, so the pink color went away and was replaced by a blue color.

Alchemists saw changes like the ones you saw in your experiment and thought that if they were just able to find the right recipe, they could mix lead with several other substances and make gold. Of course, we now know that this is impossible, because we know that there are severe limitations on how much one substance can change in a chemical reaction. You will learn all about that when you take chemistry. The alchemists didn't know this, however, so they strove to mix substance after substance with lead, hoping one day to find the "magic" mixture that would turn lead into gold.

As alchemists began mixing and recording, many interesting things were observed. These observations were written down, and, every once in a while, one of the mixtures would form some useful substance. The recipe to make this useful substance would then be recorded, and the alchemist would proceed on to the next mixture. Like ancient Egyptian medicine, then, the alchemists (and most "scientists" of this time) really just did things by trial and error. They never tried to use their observations to draw conclusions about how the natural world works. Instead, they were content to just write down their observations and move on to the next experiment, searching for the next useful substance they could make.

Interestingly enough, even though the ideas of Rome held great sway in most of the known world, the Roman Empire itself began to crumble. As that happened, trade and large-scale communication became harder and harder. Since science thrives on the free exchange of ideas from one scientist to another, this put another roadblock in the way of scientific progress. Many historians refer to this period as the **Dark Ages**, because compared to the previous time period in history as well as the next time period in history, little was learned.

So here we find another lesson we can learn from the history of science: **Scientific progress depends not only on scientists, but it also depends on government and culture**. Since the Romans actively discouraged science and concentrated on inventions, the progress of science slowed. Since the crumbling government caused trade and communications to become more difficult, scientific progress slowed even more. For science to proceed, then, the government and the culture must support it.

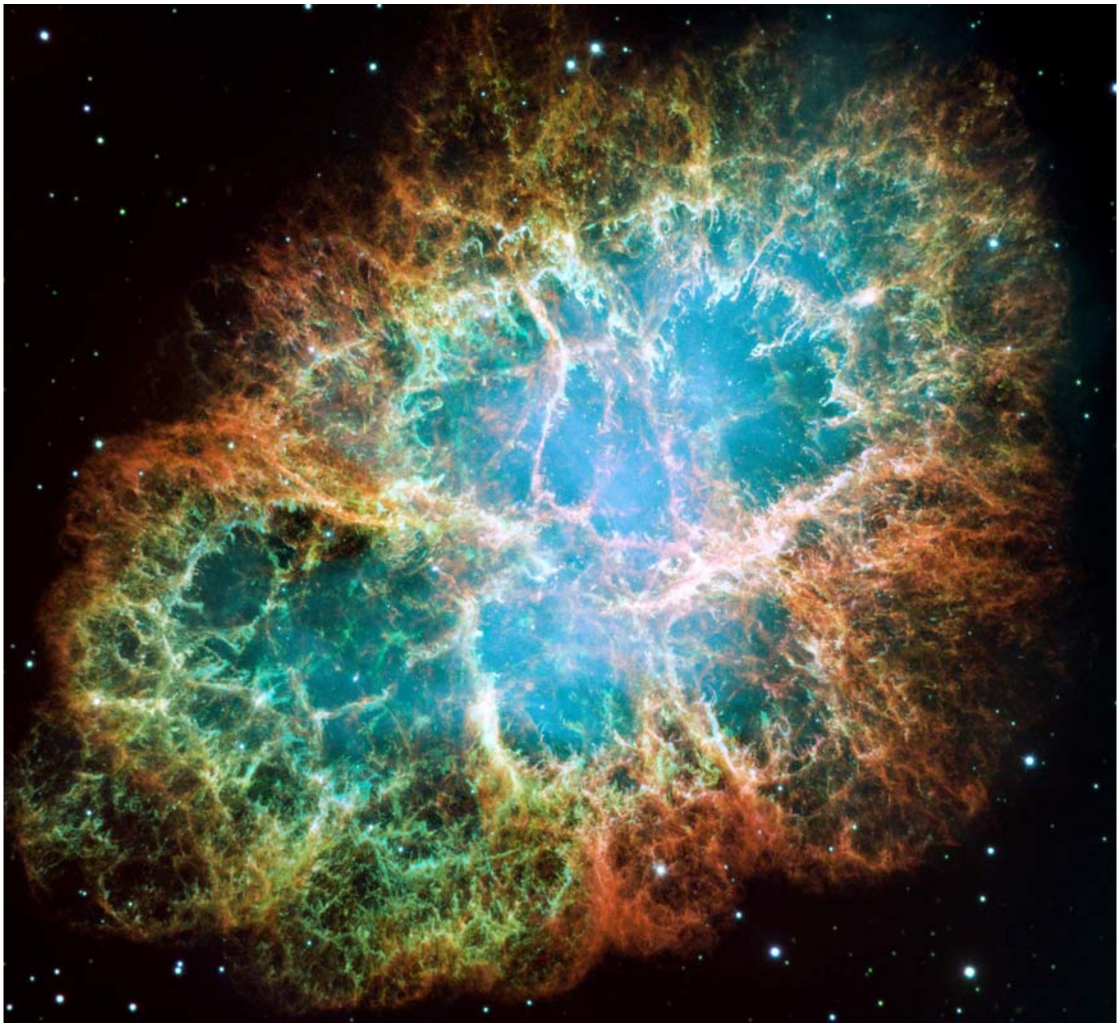
Although the progress of science slowed during this period, there are a few things worth noting. Most of the knowledge that had accumulated up to this point was carefully preserved by Roman Catholic monks. These monks, and Christians in general, believed that God had revealed Himself to His creation in two ways: through Scripture and through nature. Thus, these monks were committed to preserving *both* means of revelation. They copied and re-copied Scripture so as to preserve it for coming generations. They also did the same with the accumulated scientific knowledge of the time. They created large volumes of scientific observations and speculations, which came to be known as **encyclopedias**. These encyclopedias, with their vast accumulation of data and ideas, were one of the main reasons science was able to flourish in the next period of history.

Another thing worth noting about this period is the fact that although real science stalled dramatically, there were still a lot of people making observations and inventing things. Both Arabs and Chinese during this time period were involved in making careful studies of the heavens. They made observations that were much more detailed and precise than those of the Greek scientists who came before them. Even though there were very few attempts to explain *what those data meant*, at least the data were being collected, and they would be used by later scientists to draw significant conclusions about the world around us.

For example, Chinese records from 1054 A.D. include detailed observations of a phenomenon that Chinese scientists called a "guest star" in the heavens. You see, the scientists were familiar with the stars and knew some formed patterns called **constellations** (kahn' stuh lay' shunz). Well, they recorded in 1054 that a star that had not been seen before suddenly appeared in a certain constellation. Although they did not understand how this "guest star" came to be, they recorded their observations in great detail. Modern scientists have been able to use those observations to determine that the Chinese had seen a **supernova**, which is essentially the explosion of a star. The observations were so detailed that modern scientists were able to look at that same part of the night sky, and when they did, they found a cloud of dust and gas, called a **nebula** (neb' yoo luh). Based on these facts, modern scientists now believe that one way a nebula forms is by the explosion of a star.

Photo courtesy of NASA

FIGURE 1.5
The Crab Nebula



Based on very detailed Chinese records from 1054 A.D., the Crab Nebula is thought to be the remains of a star that exploded.

Once again, then, we come to another lesson in the history of science: **Science progresses by building on the work of previous scientists**. Had the monks of this time period not catalogued and preserved the thoughts and observations of the scientists who had come before them, the scientists who came after them would not have had a foundation upon which to build. Had the Chinese not recorded such detailed observations of the night sky, modern scientists might still not know where the Crab Nebula came from. Thus, in order for science to advance, we must study and preserve the works of the scientists who come before us. As more and more scientific knowledge is accumulated, this becomes a more and more important task.

Another thing worth noting about this time period is that the Christian church (mostly the Roman Catholic Church) was instrumental in continuing the progress of medical treatment. The works of previous scientists were studied in monasteries, because Christians believed it was their duty to aid and comfort the sick. Thus, the medical advances up to this period in history were preserved and practiced throughout the Dark Ages. In addition, although no real understanding of the human body emerged, more trial-and-error medicine such as that practiced by the ancient Egyptians did lead to advances in the treatment of illness.

ON YOUR OWN

1.6 A great many scientists today worry that most students do not appreciate science. As a result, there are those who worry about the future of science. Although it is true that most young people today don't care about science, there are some who do. They will obviously become the scientists of the future. Since there will always be at least a few people who are interested in science, why are today's scientists worried about the future of science?

Science Begins To Pick Up Steam (1000 A.D. to 1500 A.D.)

Towards the end of the Dark Ages, real science slowly began to emerge again, thanks mostly to the Roman Catholic Church. Remember, science slowed considerably at the beginning of the Dark Ages due to the influence of the Roman Empire, which had little regard for real science. One of the reasons it held science in such low esteem was due to the predominant religion of the Roman Empire. The Romans believed in many gods. These gods roamed the universe, alternately torturing or helping humans, depending on their whims. With such a religion, there was no reason to believe the natural world could be explained. After all, the gods' actions were unpredictable. Thus, the Romans reasoned, the natural world itself (which was the creation of the gods) must also be unpredictable. As a result, Romans believed that the natural world simply could not be explained in any consistent way.

By about 1000 A.D., however, Christian scholars began realizing that their beliefs promoted a completely different way of looking at the world around them. They believed in a single God who created the universe according to His laws. Since they believed that God's laws never changed, they realized that the natural laws God set into motion should also never change. As a result, the way that the natural world worked could be explained, as long as scientists could discover the natural laws that God set into motion.

It might seem painfully obvious to you that the natural world must obey certain laws. However, that kind of thinking was relatively revolutionary at the end of the Dark Ages. Now realize that this kind of thinking wasn't really *new*. It was just different from the predominant idea of the day. After all, Greek scientists like Aristotle and Ptolemy also believed that the natural world could be explained by laws that did not change. Nevertheless, that part of their thinking was mostly ignored during the Dark Ages, due to the influence of Roman thought.

A very important figure in this time period was **Robert Grosseteste** (groh' suh test' ee). Grosseteste was a bishop in the Roman Catholic Church in the early 1200s A.D., and he was deeply committed to the idea that the secrets of the natural world could be learned by discovering the laws that God had set in motion. He taught that the purpose of inquiry was not to come up with great inventions, but instead to learn the *reasons* behind the facts. In other words, he wanted to explain *why* things happened the way they did. That's the essence of science.

Grosseteste taught that a scientist should make observations and then come up with a tentative explanation for *why* the observed events happened. The scientist should then make more observations to test his explanation. If the new observations confirmed the explanation, the explanation might be considered reliable. If the new observations contradicted the explanation, the explanation was probably wrong.

As you will learn in the next chapter, that is essentially the method we use in modern science. Thus, Grosseteste is often called the father of the scientific method, because he was the first to thoroughly explain and use it. Grosseteste applied his scientific method to the problem of explaining the rainbow. Although Grosseteste never developed a satisfactory explanation for the rainbow, a Roman Catholic priest who lived roughly 50 years later, **Dietrich Von Freiberg**, built on Grosseteste's work and was able to offer an explanation for why a rainbow appears in the sky. Because of that, Von Freiberg is often called "the priest who solved the mystery of the rainbow." Next year (in physical science), you will learn how a rainbow forms.

Although Grosseteste is considered the father of the scientific method, one of his followers, **Roger Bacon**, is more famous and is sometimes given that title in error. Bacon staunchly advocated the use of Grosseteste's method. He tried over and over again to use science to break the shackles of superstition. For example, conventional wisdom in Bacon's day was that a diamond could be broken only by the application of goat's blood. He proposed experiments that, when performed, showed that goat's blood had no effect whatsoever on diamonds.

Bacon also had a strong belief that science could be used to support the reality of Christianity. A devout Roman Catholic theologian, Bacon believed that the more people learned about science, the more they would learn about God. In addition, Bacon seemed to see the potential of science when few others did. In his writings, he predicted that science would bring about marvels such as flying machines, explosives, submarines, and worldwide travel. People laughed at his ideas back then, but historians today marvel at his insight.

Roughly 70 years after Bacon (in the early 1300s), another important figure, **Thomas Bradwardine** (brad war' deen), emerged on the scene. Bradwardine was a bishop in the Roman Catholic Church, and his work was important on two levels. First and foremost, Bradwardine was a theologian who questioned much of the Roman Catholic Church's teachings. Many church historians consider him the first Reformer, because he emphasized salvation by faith alone, through the grace of God. The more well-known reformers (Luther and Calvin) were heavily influenced by Bradwardine's work.

Not only was Bradwardine an important figure in church history, he was also important in the development of modern science. Bradwardine was one of the first scientists to examine many of Aristotle's ideas critically. He found most of them lacking. He concentrated on understanding motion. He wanted to know why things moved, what kept them moving, and what made them stop. He applied mathematics to his study of motion and actually developed equations in an attempt to describe the details of speed, distance traveled, and so forth. Using mathematics and experiments, he was able to show that most of what Aristotle said about motion was wrong. Although it took nearly 300 more years for science to throw away Aristotle's ideas about motion, it might never have happened without Bradwardine's work.

Another important scientist of this era was **Nicholas of Cusa**. He was also a priest in the Roman Catholic Church in the mid-1400s and became an influential leader in the church toward the end of his life. He was particularly interested in the idea that God was infinite. Because he wanted to learn more about God's infinite nature, he studied the planets and the stars, thinking they were probably the largest (and thus closest to infinite) things that he could study. His studies of the planets were revolutionary because he was one of the first to break from Ptolemy's geocentric view. He (correctly) believed that the earth spins while it travels around the sun. This was in direct disagreement with Ptolemy's ideas, and it laid the groundwork for the scientific revolution that would take place two hundred years later.

Before I end this section, I want to make sure that you have picked up on something. Notice that many of the great scientists of this era were devout Christians. In fact, many were clergy (priests, bishops, etc.) of the Roman Catholic Church. As you read through the rest of this module, you will notice that many of the great scientists from the Dark Ages to modern times were devoted Christians. Once again, that's because the Christian worldview is a perfect fit with science. Science is based on the notion that the world works according to rational laws that do not change. Since Christians believe in a rational Creator whose laws do not change, science and Christianity work very well together.

That last statement surprises some people. Some people actually believe that science and Christianity are at odds with one another. Unfortunately, that myth has developed recently, mostly because the majority of scientists today are not Christian. However, even a quick look at science history tells us that without Christianity, science would never have gotten out of the Dark Ages. The Christian worldview was essential in turning trial-and-error-based observations into true science. The more you learn about the history of science, the more you will see that science would never exist in its present form had it not been for Christianity!

ON YOUR OWN

1.7 Some historians call Grosseteste the first modern scientist. Why does Grosseteste deserve that honor?

The Renaissance: The "Golden Age" of Science (1500 A.D. to 1660 A.D.)

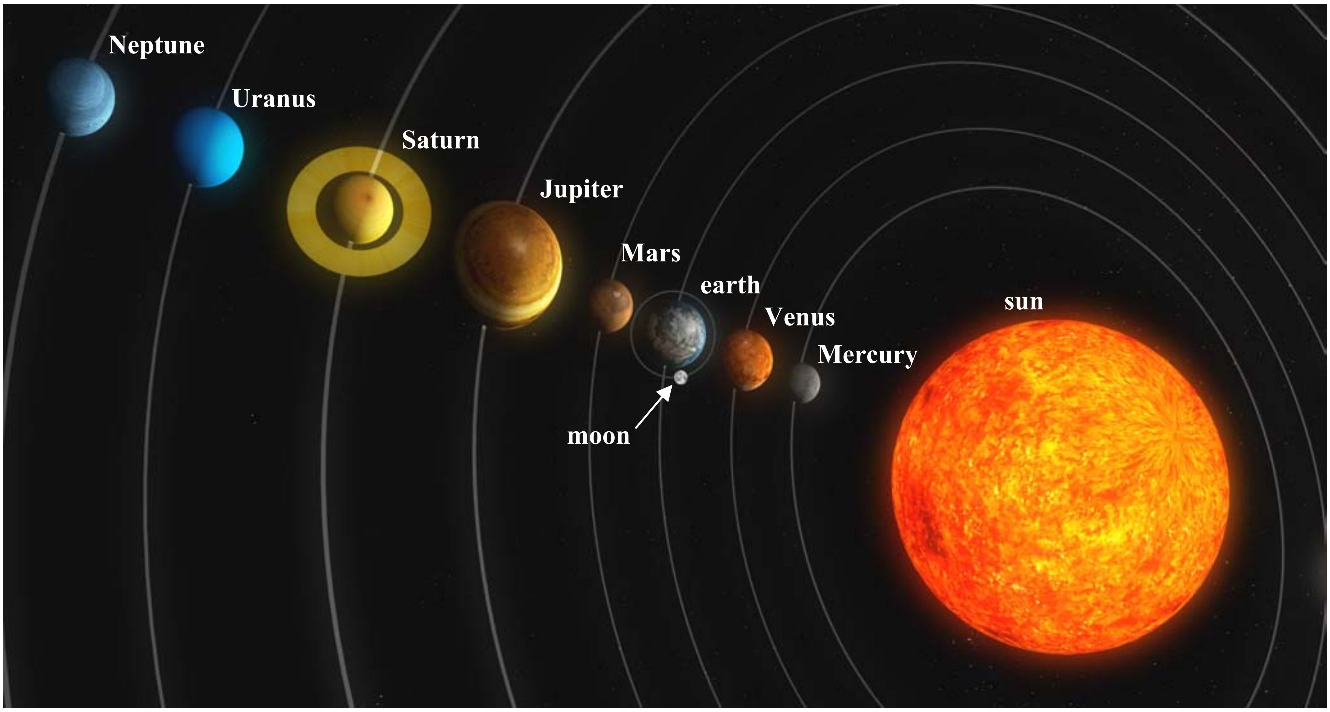
The 16th and 17th centuries (1500 A.D. to 1700 A.D.) were incredibly exciting in the history of science. The excitement took off in 1543, when two very important works were published. The first (and most celebrated today) was published by **Nicolaus Copernicus**. It was a book that laid out his idea about the earth, sun, planets, and stars. Like Nicholas of Cusa, Copernicus believed that Ptolemy's view of the universe was wrong. Rather than placing the earth at the center of everything and believing that the sun and the planets traveled around the earth, Copernicus placed the sun at the center of everything and assumed that the planets (including the earth) traveled around the sun. This view was called the **heliocentric** (he' lee oh sen' trik) **system**, because Helios is the Greek god of the sun. Sometimes, however, it is called the **Copernican system**, in honor of Copernicus.

Copernicus had actually completed his studies and written his book nearly 13 years before it was published. However, Copernicus delayed its publication because the Roman Catholic Church disagreed with the heliocentric system. This fact was a little ironic, as Copernicus himself was part of the church's clergy and had actually done his work at the request of the pope, who was the head of the Roman Catholic Church! Nevertheless, the Roman Catholic Church publicly denounced Copernicus' work and put his book on their list of prohibited reading. As I mentioned in a previous section, the church did this not because of science, but because of preconceived notions. The Roman Catholic

Church liked the idea of the earth being at the center of everything, and they therefore did not want to give up Ptolemy's geocentric view.

FIGURE 1.6
The Heliocentric System

Illustration by Sebastian Kaulitzki
Agency: www.shutterstock.com



Copernicus championed the heliocentric view, where the planets travel around the stationary sun in circular orbits. Unlike the geocentric view, there are no epicycles. The circles in the drawing show the actual paths of the planets. This is the modern view of how the sun and planets are arranged. Mercury is closest to the sun, followed by Venus, earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The moon is not a planet, but travels around the earth while the earth travels around the sun.

The other important work published in 1543 was written by a doctor named **Andreas Vesalius** (vuh sal' ee us). It was a book that tried to show all the details of the human body. It contained incredibly detailed and amazingly accurate illustrations of the organs, muscles, and skeleton of the human body. This was the first book that illustrated all of the "insides" of the human body, and it revolutionized how medicine was taught.

Although the importance of Vesalius' book was recognized right away, it took longer for people to recognize the importance of Copernicus' work. The first reason, of course, was the fact that the Roman Catholic Church banned the book. The second reason was that although Copernicus had the right idea, he had very little data to back it up. Copernicus promoted his heliocentric system not because he had made a lot of observations that supported this view, but because he knew that there was a lot of evidence *against* Ptolemy's geocentric view. Copernicus also thought that God fashioned the heavens using the heliocentric system because it was the more orderly and pleasing of the two.

Copernicus' heliocentric view became more and more accepted as more and more evidence for it was compiled. One of the most important compilers of such evidence was **Johannes Kepler**. Kepler began making observations of the heavens in the late 1500s. He desperately wanted to be a minister, but he had terrible financial problems that forced him to accept a job as a teacher instead. While he taught, he studied the heavens, hoping his observations would bring glory to God. In a particularly revealing letter, he wrote, “I wanted to become a theologian. For a long time, I was restless. Now, however, behold how through my effort God is being celebrated in astronomy” (*Scientists of Faith*, Dan Graves, Kregel Resources, 1996, p. 49).

Kepler made detailed observations of the planets. His observations were so detailed that he was able to deduce the basic orbits the planets use to travel around the sun. He was even able to describe these orbits mathematically. His mathematical equations became known as “Kepler’s Laws,” and they became one of the most powerful arguments for the heliocentric system. Kepler’s observations of the planets were so detailed and precise that he was able to determine something very interesting about the planets. His data showed that the planets don’t really travel around the sun in circles. They actually travel around the sun following an oval pattern, which mathematicians call an **ellipse** (ee’ lips). Perform the following “experiment” to learn about how the planets *really* travel around the sun.

“EXPERIMENT” 1.4

Mapping the Paths of the Planets

Supplies:

- A pencil
- A sheet of paper (8 ½” by 11”)
- Six thumbtacks or pushpins
- A piece of string 8 inches long
- A sheet of cardboard larger than or the same size as the sheet of paper

Introduction: Planets travel around the sun in ellipses, not circles. This “experiment” helps you to understand what that means.

Procedure:

1. Lay the sheet of paper on top of the cardboard.
2. Pin it to the cardboard at each corner.
3. Lay one end of the string about 2 inches left of center, halfway down the paper.
4. Pin it to the paper so it is held there.
5. Push the last pin you have through the string about 5 inches away from the pin that is attached to the paper and cardboard.
6. Use this pin to attach the string to the paper about 2 inches to the right of center, straight across from the end of the string that is already taped down. There will be some excess string dangling off the pin. That’s fine.
7. Take the pencil and push the point against the string above the two pins so the string becomes tight.
8. Keeping the string tight at all times, move the pencil from one pin to the other, drawing a curve on the paper. If you keep the string tight, it will guide your pencil. The end result will be a line that begins just above and to the right of the right pin and curves around to and left of the left pin, as shown in the drawing on the right.

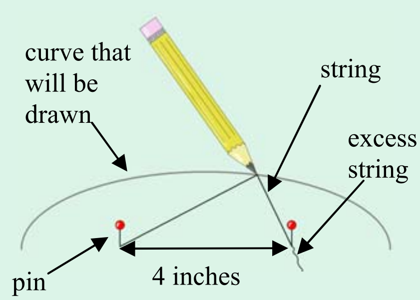


Illustration by Megan Fruchte

9. Repeat the process, this time starting *below* the two pins, keeping the string tight at all times. The result will be a curve that looks like a reflection of the first curve you drew.
10. Now look at what you have drawn. It is an oval, which mathematicians call an ellipse.
11. Pull the right pin off the paper and out of the string.
12. Push that same pin through the very end of the string.
13. Push the pin and string into the paper at the same place the pin was before. This setup should look very similar to the previous one. The pins will be in the same place, but there will be more string in between the pins and no excess string dangling from the right pin.
14. Once again, use the pencil and string to draw two curves: one below the pins and one above them. Keep the string tight at all times, allowing it to guide the pencil in making the curves.
15. Remove the tape and string from the paper and look at the two ellipses you drew.

Both of the drawings you made are ellipses. An ellipse is defined by two points called **foci** (foh' sye – the singular of which is **focus**). In your "experiment," the foci were the two pins. If you were to take any point on the first ellipse you drew and measure the distance from that point to each pin, the sum of those two distances would be 5 inches. That's the property of an ellipse. The sum of the distances from any point on the ellipse to each of the foci is always the same. On the second ellipse you drew, the sum of those distances would be 8 inches, because the string was longer when you drew the second ellipse.

Now don't worry if you do not completely understand ellipses. The main point I want you to understand is the difference between the two ellipses you drew. The second one is more circular than the first, isn't it? That's because the string was longer the second time, but the foci were the same. The ellipses in which the planets travel around the sun are very nearly circular. Thus, they are much more like the second ellipse than the first. Well, if the second ellipse you drew is like the orbit of a planet, where is the sun? The sun is at one of the two foci. In the end then, the planets do not travel around the sun in perfectly circular orbits. They travel in ellipses. Also, the sun is not exactly in the center of the ellipse. Instead, it is at one of the foci.

Other powerful evidence for the heliocentric view came from a scientist named **Galileo** (gal uh lay' oh) **Galilei** (gal uh lay'), who is usually referred to by just his first name. Galileo was a well-known, well-respected scientist for many reasons. He did detailed experiments about motion, confirming the work of Bradwardine and showing the flaws in Aristotle's thinking. Galileo started seriously compiling evidence in favor of the heliocentric system in 1609, when he built his first telescope. While many works claim that Galileo invented the telescope, he did not. He heard about a device that was designed for the military by Hans Lippershey. It was essentially a "tube" with two lenses, and it magnified distant objects. From the description he heard, he was able to determine how this invention worked and quickly built one for himself. So was Hans Lippershey the real inventor of the telescope? We don't really know. However, he is the first name that history associates with the device.

As Galileo worked with telescopes, he made several improvements to the design and also collected volumes of data about the planets and the stars. He was able to show that the planets do not shine on their own. He demonstrated that the planets appear as lights in the night sky simply because they reflect the light of the sun. In addition, he showed that the light coming from Venus went through phases, just like the moon. Facts like these made it clear that the heliocentric view was superior to the geocentric view. Unfortunately, the Roman Catholic Church would not let go of the geocentric view and put Galileo on trial for heresy. In that trial, the church demanded that Galileo publicly recant his belief in the heliocentric system. Because Galileo was a devout Roman Catholic, he obeyed the church and publicly "denounced" the heliocentric view. Nevertheless, he kept collecting data. Well after his death, Galileo's data (along with Kepler's laws) simply proved too powerful for the Roman Catholic Church to ignore, and the heliocentric system was eventually accepted as the correct view of the heavens.

FIGURE 1.7
Scientists Who Corrected Our View of the Heavens

Copernicus's work argued strongly for the heliocentric system, saying it was the way an orderly God would have created the heavens.

Kepler's observations and the laws he derived from them provided strong evidence for the heliocentric system.

Galileo's telescopic observations could only be explained by using the heliocentric system.

Even though the advances in understanding the heavens take center stage in the history of this time period, many other scientific advances took place as well. **Blaise** (blayz) **Pascal** (pas kal') lived in the mid-1600s. He was a brilliant philosopher, mathematician, and scientist. If you have studied Christian apologetics at all, you might remember him as the author of "Pascal's wager." This argument presents a person's worldview in terms of a bet. He then argues convincingly that Christianity is, by far, the best bet.

In addition to his philosophy, Pascal is also well remembered for his work as a mathematician and scientist. In math, he made several advances in the understanding of both geometry and algebra. In science, he spent an enormous amount of time studying the air and liquids. He demonstrated that the air we breathe exerts pressure on everything, an effect we call **atmospheric pressure** today. In his studies of fluids, he demonstrated a law that we now call "Pascal's Law." The science behind that law allowed us to develop hydraulic lifts, like the lift a mechanic uses to raise a car so he can get underneath it.

ON YOUR OWN

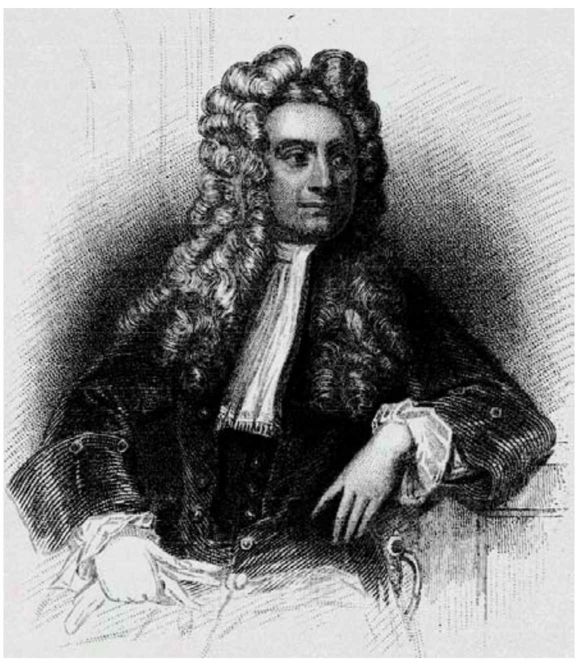
1.8 Galileo faced a very difficult decision in his life. He was convinced by science that the heliocentric system was correct. Nevertheless, his church said that he was wrong and threatened to throw him out if he didn't recant his belief in the heliocentric system. Galileo, in obedience to his church, agreed to publicly recant his belief, even though he knew it was right. Did Galileo make the right choice, or should he have stayed true to his science and been thrown out of the church?

The Era of Newton (1660 A.D. to 1735 A.D.)

Although the Renaissance is often called the "golden age" of science, I personally think that science enjoyed its greatest advancement during the time of **Sir Isaac Newton**. As is the case with many of the great scientists of the past, Newton was a devout (though unorthodox) Christian. He studied science specifically as a means of learning more about God, but he never forgot that the best way to learn about God was by thorough Bible study. He wrote many commentaries on the Bible, concentrating on prophecy. He was particularly drawn to the Book of Daniel. In his later years, he spent a lot more time writing about the Book of Daniel than he did writing about science.

FIGURE 1.8
Sir Isaac Newton

Image in the public domain



To call Sir Isaac Newton brilliant would be an understatement. In his short lifetime, Newton laid down three laws of motion that still guide the science of physics today. He formulated a universal law of gravitation, which is also still used to this day. In his studies of motion, he realized the mathematics of his day was not complete enough to help him understand his data. Thus, he developed an entirely new mathematical field we now call calculus, and it continues to be an essential tool in many fields of science. He also did the famous prism experiment that shows white light is really composed of many different colors of light. In addition, he came up with a completely different design for telescopes, a design that is still used in many of today's telescopes. It is little wonder that many science historians call Sir Isaac Newton the greatest scientist in history.

Newton wrote most of his revolutionary scientific work in a three-volume set we call the *Principia* (prin sip' ee ah). In the first volume, Newton laid down three laws of motion. You will learn about these laws next year when you take physical science. In formulating these laws, Newton made a direct link between mathematics and science. In essence, Newton proposed that a scientific law was useless if it could not be used to develop a mathematical equation that would describe some aspect of nature. The deep link that Newton established between science and math resulted in a major breakthrough. Although many scientists in the past had used mathematics to analyze a scientific problem, Newton was the first to establish an intimate link between the two. This link helped turn scientific research into a detailed, rigorous field of study.

In the second volume of the *Principia*, Newton built on the work of Pascal and added many details to the understanding of the motion of fluids. In the third volume, Newton laid down his universal law of gravitation. The term "universal" has a specific meaning here. You see, scientists in Newton's day thought that the reason an object falls when dropped was due to one physical process, while the reason the planets moved in the sky was due to a completely different process. Newton showed that this was not the case. In volume three of the *Principia*, Newton used detailed experiments and observations to show that gravity was the cause of both effects. The same gravity that attracts objects to the earth (making them fall) also keeps the planets in their orbits around the sun. In addition to his experimental results, Newton had (of course) developed detailed mathematical equations that describe gravity. Those mathematical equations are still considered accurate to this day. The third volume of the *Principia* essentially was the final death blow to the geocentric view of the heavens.

Although Newton took center stage during this time period, there were other great scientists who brought about other significant advances as well. **Robert Boyle**, the founder of modern chemistry, was a contemporary of Newton. He did many experiments with gases, formulating laws that are still used today in chemistry. In fact, when you take chemistry in high school, you will undoubtedly learn about Boyle's Law. Boyle was also a dedicated Christian, who often wrote sermons using nature to give glory to God. His last words to the Royal Society (a group of scientists in England) were "Remember to give glory to the One who authored nature" (*Scientists of Faith*, Dan Graves, Kregel Resources, 1996, p. 63). Unfortunately, those words were eventually forgotten.

Another notable scientist from this period was **Antoni** (an' ton ee) **van Leeuwenhoek** (loo' en hook). Although not educated as a scientist, Leeuwenhoek revolutionized the study of life by building the first **microscope**. His microscope allowed him to see a world that had been invisible up to this point, which enabled him to discover many tiny (microscopic) life forms, including bacteria. The existence of these life forms helped scientists explain many things that had been, up to this point, complete mysteries. Like Boyle, Leeuwenhoek tried to glorify God in all his scientific work. To him, the existence of a microscopic world was just one more testimony to the fact that God made *all* creatures – great and small.

ON YOUR OWN

1.9 Some students think mathematics is too difficult to learn. In order to teach science to such students, there are many science textbooks written today that do not use mathematics at all. What do you think Newton would say about such textbooks?

<u>The "Enlightenment" and the Industrial Revolution (1735 A.D. to 1820 A.D.)</u>

This period in history marks the beginning of a change in the underlying assumptions of science. A philosopher of the time, Immanuel Kant, used the term **Enlightenment** to describe this change. Unfortunately, the change was only partially beneficial to the progress of science, so I always put the term in quotes, because the change that began in this period was only partially enlightened.

What is this change to which I refer? Well, up to this point in history, God was at the center of virtually all science. As you can see from the previous sections, most of the great scientists up to this time in history were devout Christians. Since most of the progress in science was being made by Christians, science had a very Christian flavor to it. You could hardly find a scientific book or paper written that did not mention God reverently. Prayer was at the forefront of most scientific meetings and assemblies. Christianity was the basis of most scientific education. At this point in human history, that began to change.

What caused this change? Ironically, the great advances in science up to this time were indirectly the cause. You see, the advances made in science from the Dark Ages up to this point in history were the result of scientists ignoring the teachings of Ptolemy, Aristotle, and the other scientists whose works had dominated science for so long. As time went on, the scientific community began to learn that scientists should not just accept the teachings of former scientists. Instead, they realized that all scientists make mistakes, and therefore everyone's work must be examined critically. In the end, then, science stopped relying on the authority of past scientists and began relying on experiments and data.

That's the *good* part of the change that occurred during the Enlightenment. Scientists stopped referring to the authority of past scientists and started examining all scientific works critically. As I already pointed out in a previous section, that's the way science *should* be done. Unfortunately, as science began to ignore the authority of past scientists, it also began to ignore the authority of the Bible. That's the *bad* part of the change that occurred during the Enlightenment. Despite the fact that a biblical worldview had brought about the very science they studied, some scientists began to question the truth of the Bible.

Of course, science's departure from a biblical worldview was not abrupt. Many scientists during this time period and beyond were (and are) devout Christians, and God was still mentioned in many scientific works. In addition, many scientists continued to take their direction from the Bible when it came to how they approached science. However, as time went on, fewer and fewer references to God and the Bible could be found in the works of science.

Although this period can be thought of as the beginning of science's departure from a biblical worldview, it is marked in history by the work of a devout Christian, **Carolus** (kair' uh lus) **Linnaeus** (lih nay' us). In 1735, Linnaeus published a book in which he tried to classify all living creatures that had been studied. This work is often used to mark the beginning of the Enlightenment, because it revolutionized the study of living things. The basic classification scheme proposed by Linnaeus is still used today, and we still give living organisms their scientific names according to the rules set down in his book.

Linnaeus was deeply committed to performing science as a means of glorifying God. He called nature God's private garden, and he continually glorified God in his scientific works. Here is a typical quote from his works: "…one is completely stunned by the incredible resourcefulness of the Creator" (*Linnaeus, the Compleat Naturalist*, Wilifrid Blunt, Princeton University Press, 2001, p. 14). In fact, it was Linnaeus' view of God that prompted him to classify living creatures. He believed that God is very organized. Thus, he believed that God's creation should be organized as well. In his mind, the classification scheme he developed was just a means of showing the organization of creation.

As Linnaeus was classifying living organisms, **Antoine-Laurent** (an twon' law rent') **Lavoisier** (luh vwah' see ay) was busy studying chemical reactions. He was the first to analyze chemical reactions in a systematic way, and he was the first to realize that matter cannot be created or destroyed – it can only change forms. This is known as the **Law of Mass Conservation**, and it was Lavoisier's most important contribution to science. Lavoisier was also the first to properly explain **combustion**, which is the process of burning.

Another important scientist in this time period was **John Dalton**. Dalton was a Quaker who attended church at least twice each week. He did many experiments with gases, and proposed many new ideas that helped guide science in the future. Perhaps his most important work was his **atomic theory**. Building on the works of Democritus and others, Dalton proposed a detailed theory about atoms. Although a few of his ideas were wrong, most of them were right, and he is considered the founder of modern atomic theory.

As scientific knowledge grew, many inventors were able to use this knowledge to invent machines that made work faster and more productive. Up to this time period, the production of almost anything was done mostly by hand. Increased scientific knowledge, however, led to the invention of many devices that turned hours of manual labor into just a few minutes of work. This changed forever the way things were made, and so this period in history is also called the **Industrial Revolution**.

The Rest of the Nineteenth Century (1820 A.D. to 1900 A.D.)

During the rest of the nineteenth century, many great advances were made in science. Partially, this is due to the fact that people began to appreciate science more. After all, in the wake of the Industrial Revolution, people realized that the inventions that made their lives better were at least partially the result of scientific knowledge. As a result, there was popular support for science. This popular support translated into better facilities and a better way of life for scientists, which in turn translated into great advances.

This period is probably best known for the work of **Charles R. Darwin**. In 1859, he published a book entitled *On The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life.* Typically abbreviated as *The Origin of Species*, Darwin's book caused a firestorm in the scientific community. In *The Origin of Species*, he proposed a theory that attempted to explain the diversity of life that exists on earth. This theory, now known as the theory of evolution, made no reference to God. Instead, it proposed that the same kinds of processes we see occurring today are, in fact, responsible for all the species on the planet. In effect, Darwin's book proposed to answer the age-old question, "How did we get here?" without ever referring to a supernatural Creator.

You will learn a lot more about Darwin himself and his theory when you take biology. You will also learn some of his theory in a few of the modules of this course. What I want to stress here is the impact of Darwin's work. First and foremost, Darwin's work finished the change that began in the Enlightenment. As Darwin's ideas caught on in the scientific community, those who wanted to ignore the authority of Scripture were empowered. After all, they reasoned, if science can explain how we got here without ever referring to a Creator, why should science continue assuming that the Creator exists? As a result, it became rarer and rarer to find references to God in the scientific literature of this or the next century.

The second impact of Darwin's work was to improve the study of living things dramatically. Now it is important to realize that I (and hundreds of other scientists) think that Darwin's idea of evolution is fundamentally wrong. Nevertheless, even wrong ideas can help advance science! Think about what you have learned up to this point. Most of the ideas proposed throughout the history of science were wrong. Nevertheless, those ideas helped move science ahead, until the correct explanation could be found. Thus, even though Darwin was wrong about much of what he proposed, he still advanced biology enormously.

How did Darwin do that? Well, up until Darwin wrote his book, most scientists thought living creatures stayed the same throughout history. In other words, scientists thought that every type of creature that exists today has existed throughout history. Consider dogs, for example. Scientists of this time period and before thought that Saint Bernards, dachshunds, and chihuahuas always existed. Each of these breeds of dog lived throughout history, essentially unchanged. This idea was called the **immutability of the species**, and Darwin masterfully showed that this just wasn't true. He showed that living organisms can adapt to changes in their surroundings through a process he called **natural selection**. Over time, this can lead to new organisms that are radically different from their ancestors.

Illustration from www.clipart.com

FIGURE 1.9
Charles Darwin

Although a lot of what Darwin proposed has been demonstrated to be incorrect, he did contribute significantly to the advancement of biology by destroying the concept of the immutability of the species. Darwin's work laid the foundations for works that now clearly demonstrate the fact that creatures have the ability to adapt to changes in their surroundings, producing new versions of old creatures. For example, Saint Bernards, dachshunds, and chihuahuas have not always existed. Instead, as the original "dog" spread out to different areas of the world, it encountered different environments. Over the generations, the dogs adapted to these different environments, producing different types of dogs. This was accentuated by breeders choosing which dogs were "desirable" and allowing only those dogs to have puppies. Over the generations, such processes produced the breeds we see today.

Even though this time period is best remembered for Darwin's work, other scientists were producing revolutionary work as well. **Louis Pasteur** was able to finally destroy the idea of spontaneous generation once and for all. He also made great advances in the study of bacteria and other living organisms. He developed a process called **pasteurization**, which he originally used to keep wine from souring. This process is now applied to milk, which is the origin of the term "pasteurized milk." Pasteur is also known for his brilliant work with vaccines. His work laid the foundation for most of today's vaccines, which have saved millions and millions of lives by protecting people from disease.

During this time period, the study of rocks became its own field, known as **geology**. Scientists began to recognize fossils for what they really are: preserved remains of creatures that were once alive. This began to help scientists come up with a better understanding of what kinds of creatures lived in earth's past. **Sir Charles Lyell** was an important figure in this regard. He broke with the scientific view of the time that the earth was a few thousand years old and postulated that the earth took millions of years to form. Once again, although the weight of scientific evidence goes against most of Lyell's ideas, his studies were extremely important to our understanding of modern geology. Another important aspect of Lyell's work is that it exerted a heavy influence on Darwin.

Gregor Mendel also performed his work during this time period. Mendel was an Augustinian monk. He was a devout Christian who devoted much of his life to the study of reproduction. The entire field of modern **genetics**, which studies how traits are passed on from parent to offspring, is based on his work. Although he loved his scientific pursuits, he gave them up in the latter years of his life because of a political struggle between the government and the church. He considered spiritual matters much more important than scientific matters, and he devoted all his energy to fighting what he saw as government encroachment on religious freedom.

During this period in history, science developed a much better understanding of electricity and magnetism. **Michael Faraday**'s experiments and ideas about electricity earned him the title of "the electrical giant." Many of the terms used in the study of electricity today are terms that were first used by Faraday. Faraday's Christian faith was well known in the scientific community. Although humble, he was not ashamed of his Christianity and would argue with any scientist who tried to refute the reality of faith. In fact, his faith led him to lay the foundations of the work of another famous scientist, **James Clerk Maxwell**.

Maxwell is known as the founder of modern physics, which puts him in the same category as Sir Isaac Newton. Maxwell worked with Faraday and was intrigued by Faraday's work and faith. Faraday believed that nature was all interconnected at a fundamental level, because he thought that all nature derived its characteristics from God. Thus, Faraday believed that electricity and magnetism were actually the result of a single process. In other words, he believed that whatever made electricity run through wires also made magnets stick to certain metals. Although Faraday could never offer evidence for this idea, he believed in it fervently.

Maxwell, who was also a devout Christian, shared Faraday's belief. He earned the title of the founder of modern physics because he was able to develop mathematical equations that showed Faraday was right, that electricity and magnetism are both different aspects of the same phenomenon, now called **electromagnetism**. Maxwell is an example of exactly what can be accomplished when you allow your science to be guided by a biblical worldview. Not only did he decide the direction of his research based on his assumptions about how God created the universe, but he was also known to pray while performing his scientific research.

Another very important scientist of this period was **James Joule**. Building on the work of Lavoisier, Joule determined that, like matter, energy cannot be created or destroyed. It can only change forms. This is now known as the **First Law of Thermodynamics**, and it is the guiding principle in the study of energy. He once penned a phrase that should be every scientist's motto: "After the knowledge of, and obedience to, the will of God, the next aim must be to know something of His attributes of wisdom, power, and goodness as evidenced by His handiwork" (*British Scientists of the 19th Century*; J.G. Crowther; K. Paul, Trench, Trubner & Co., Ltd.; 1935; p. 138).

ON YOUR OWN

1.10 As I mentioned in the text, even scientific ideas that are wrong can still lead to advances in science. Besides the scientists mentioned in this section, name another famous scientist that proposed wrong ideas that still advanced science.

Modern Science (1900 A.D. to the Present)

Near the end of the nineteenth century, there were scientists who thought that science had discovered almost all there was to discover about nature. After all, due to the work of Newton and others, scientists could chart the planets in their courses and knew a lot about stars and the rest of space. Those who studied living things had learned volumes about the microscopic world and were in the process of classifying all the organisms known to the human race. With the work of Mendel and others, scientists were finally beginning to understand the complex process of reproduction. Because of the work of Maxwell and others, electricity could be described, and its relationship to magnetism was well understood. The laws of motion as laid down by Newton seemed to explain nearly every aspect of motion that could be studied. As a result, some thought that science had essentially run its course, and there was not much new to be learned.

All this changed in 1900, when **Max Planck** produced a revolutionary idea. In order to explain certain experiments that could not be explained in terms of Newton's laws, Planck proposed an ingenious idea: Much like matter exists in tiny packets called atoms, energy exists in tiny packets, which he called **quanta** (quan' tah). This idea was revolutionary. After all, Newton and the scientists who built on his work believed that you could give *any* amount of energy to an object. If you want to throw a baseball, you can throw it at any speed you desire, as long as you are strong enough. This is not what Planck proposed. He proposed that energy comes in tiny packets. You can give one packet of energy to an object, or you can give two packets of energy to an object. You cannot, however, give an object any amount of energy in between one and two packets.

Now this idea might seem a little weird to you, but it is no weirder than the idea that matter exists in tiny packets called atoms. You can gather one atom of matter or two atoms, but you cannot gather any amount in between. It is essentially the same for energy. Planck produced a lot of evidence for his idea, and after a long while, it became accepted by the scientific community. Eventually, an entirely new way of looking at energy and matter, called **quantum mechanics**, was formed as a result of Planck's idea.

One of the most famous scientists in quantum mechanics was **Albert Einstein**. Einstein used Planck's idea of energy quanta to explain a problem that had perplexed scientists for years. This problem, called the "photoelectric effect" could not be explained by Newton's laws of motion, but could be easily explained by assuming that Planck was right about energy quanta. Despite the fact that Planck produced evidence for his proposition, and despite the fact that Einstein was able to explain a supposedly "unexplainable" problem using the idea of energy quanta, scientists did not want to believe that Planck was right. After all, Newton's laws had been so successful at explaining so much of physics that scientists did not want to believe there was something wrong with them.

As time went on, however, more and more evidence rolled in that showed Planck was right. One of the pivotal cases was made by **Niels Bohr**. Bohr developed a picture of the atom, which we call the **Bohr Model**. This picture of the atom was based on solid mathematics, and it required the assumption that energy comes in small packets. Using the Bohr Model, many of the mysteries of the atom were revealed. In the end, the weight of the evidence overwhelmed the scientific community's devotion to Newton's laws, and quantum mechanics became the new guiding principle in science.

Now it is important to note that quantum mechanics does not really contradict Newton's laws. Newton's laws are still considered valid today. However, we now realize that Newton's laws are simply an *approximation* of quantum mechanics. When the objects you study are large, Newton's laws are valid, because they are equivalent to the laws of quantum mechanics. However, as the size of the object decreases, there are differences between the laws of quantum mechanics and Newton's laws. In those cases, the laws of quantum mechanics are correct. Thus, Newton's laws are useful for large objects (objects we can see), but for tiny objects (like atoms), the laws of quantum mechanics must be used.

FIGURE 1.10

Three Important Figures in Quantum Mechanics

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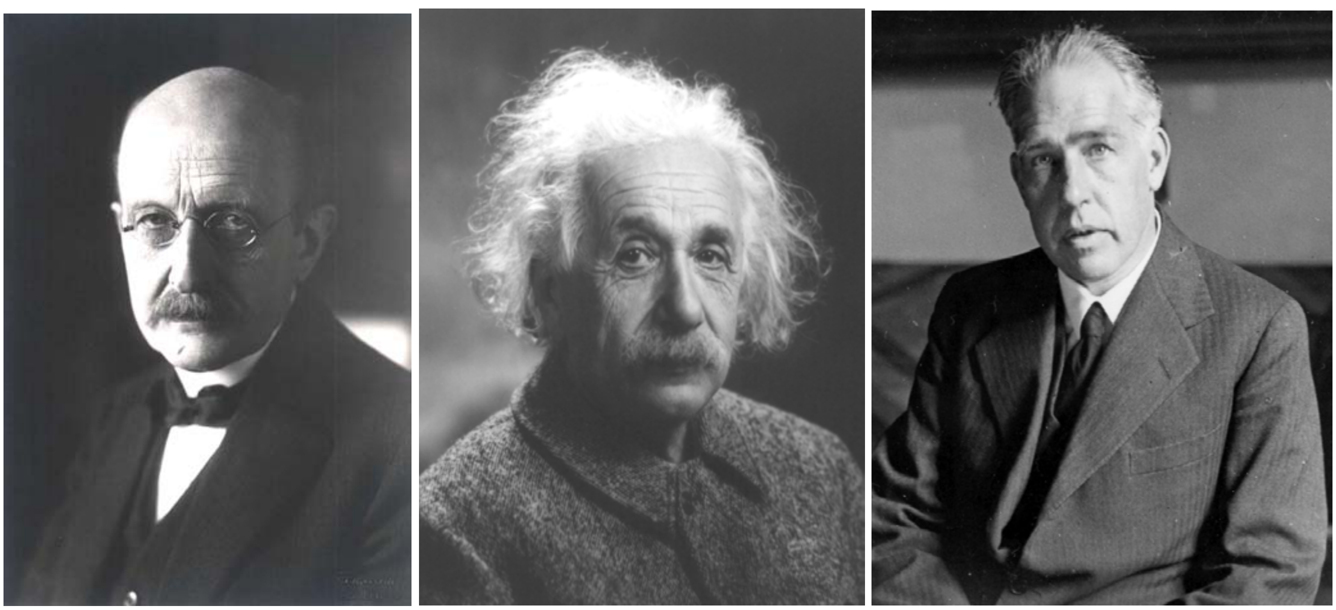


Max Planck was the first to propose that energy came in small "packets." This has led science historians to call him the father of quantum mechanics.

Albert Einstein used Planck's idea to develop an explanation for one of the most puzzling effects in physics, known as the photoelectric effect.

Niels Bohr used Planck's idea to develop a mathematical description of the atom. This description allowed scientists to understand experiments they were previously unable to understand.

Although I first mentioned Einstein in terms of the quantum mechanical revolution, he is also an important figure in many other areas of science. For example, Einstein developed a new way of looking at light, matter, and gravity. His **special theory of relativity** explained how matter is really just another form of energy. He used this theory to explain the famous equation $E=mc^2$, which says that matter can be converted to energy and vice versa. Einstein also developed the **general theory of relativity** which is an explanation of *how* gravity works. You will learn more about both of these theories when you take physical science.

Quantum mechanics and relativity have become the guiding principles of science today. The knowledge gained from these ideas has led to numerous advances in medicine, technology, and industry. In many ways, these advances have made life easier for everyone. People live longer today, there are fewer diseases, there is more food per person today than ever before, and increased productivity has led to increased material prosperity. Also, we simply have a clearer picture of *how* creation works. With all these advances, however, do not fall into the trap of thinking we have "figured it all out." Remember, scientists thought that was the case more than 100 years ago. Look what we have learned since then! Science is constantly uncovering new ideas and new ways of looking at things. That's what makes science interesting!

Summing It Up

I hope you have gained something from this overview of science history. If you don't like history, I hope you have at least learned a few lessons from the mistakes scientists have made in the past. If you can learn from those mistakes, you will be a better scientist in the end.

Before you finish with the module, however, I need to make two points. The first is about philosophy. The history of science is rich and detailed. Entire books have been devoted to just portions of the history of science. Thus, there is *no way* I could have covered everything about the history of science in just one module of this course. I am sure there will be some who dispute what I have chosen to cover. Nevertheless, in my opinion, given the constraints of one module, I have presented to you a solid view of how science got to where it is today. I have certainly left a great many things out, so don't think this is the full story. It is, however, a reasonable overview.

The second point I need to make is more practical. You are eventually going to take a test over this. You should be wondering what you need to study. Well, on page 33, you will find a study guide that helps you understand what I consider to be the important material from the module. That ought to help you focus your study for the test. As you work through the study guide, you will see that I do not want you to memorize dates. Rather, I want you to remember the major names and what they were responsible for.

Even though the study guide helps you focus on what to study, there is still *a lot* of information you will need to know for the test. How can you possibly remember it all? Here is a suggestion: Since the study guide covers the material I think is important, make some study aids based on the study guide. For example, I like to make notecards when I have a lot of information to keep straight. On one side of the notecard, I will write a term, a name, or a concept. On the other side, I will write what I need to know about it. For example, the first thing you will see on the study guide is a list of the vocabulary words you need to know. Write the word on one side and the definition on the other. The third question asks, "Who was Imhotep?" Write "Imhotep" on one side of the card and who he was on the other. Once you have done this for the entire study guide, go through your stack of notecards a few times. First, look at one side (the name, for example), and then try to say what is on the other side of the notecard (who he was). Then, *turn the notecards over and go through them the other way*. Thus, when you get to the card about Imhotep, you will look at who he was and then try to say his name. You will be amazed at how well this helps you remember things!


The multimedia CD has a review of some of the great scientists discussed in this module.

ANSWERS TO THE "ON YOUR OWN" PROBLEMS

1.1 If you look at the definition of science, it contains two parts. Science consists of collecting facts, but it also consists of using those facts to explain the world around us. <u>The Egyptian doctors and the inventors of the ancient world collected lots of facts, but they did not use them to explain the world around them</u>.

1.2 The more tightly packed the matter in a substance, the farther down it fell in the glass. Since density is a measure of how tightly the matter is packed in a substance, the farther the substance fell in the glass, the denser it was. Thus, the least dense item was the cork, and the most dense item was the stone. The vegetable oil was more dense than the cork, but less dense than the water. Continuing that kind of reasoning, then, the order is <u>cork, vegetable oil, ice cube, water, grape, syrup, rock</u>.

1.3 Experiment 1.2 demonstrated that the warmer the substance is, the faster its atoms move. To make ice from water, you must cool the water. Thus, ice is colder than water, which means <u>the atoms in ice move more slowly than those in water</u>.

1.4 Despite the fact that Dr. Hawking is brilliant, he can be wrong, just like many other brilliant scientists. <u>The story of spontaneous generation</u> tells how Aristotle was wrong, despite the fact that he was the greatest thinker of his time. <u>The story of the geocentric system</u> also tells how a great thinker turned out to be wrong. Either story should illustrate that we should not make scientific decisions based on *people*. Instead, we should make them based on *data*.

1.5 <u>The story of the geocentric system</u> tells us we must leave personal bias behind when doing science. The Roman Catholic Church held onto the geocentric system too long because of bias, not data.

1.6 <u>Today's scientists are worried about the future of science because the progress of science depends on cultural support</u>. Science stalled in the Dark Ages due to the Roman culture. If our culture stops supporting science, science will stall again.

1.7 <u>Grosseteste is the first modern scientist because he was the first to work with the scientific method</u>.

1.8 There is no right or wrong answer to this question. You must decide for yourself. Personally, my church means a lot to me. However, I would probably get kicked out rather than give up a belief I truly thought was correct. Since churches are the products of human beings, they are flawed. Only God and Christ are perfect. Thus, a church can be wrong, even about spiritual issues. Of course, I could be wrong, too. If so, I could end up being kicked out of my church for no good reason!

1.9 <u>Newton would not like such textbooks</u>. Newton believed that science had to be linked to math.

1.10 There are several possible answers to these questions. <u>Any one of the first three scientists</u> all advanced science but were wrong. <u>Democritus, Leucippus, Aristotle, Ptolemy, Newton, and many others</u> all advanced the cause of science, but they were all wrong about certain things.

STUDY GUIDE FOR MODULE #1

1. Define the following terms:

a. Science
b. Papyrus
c. Spontaneous generation

2. There were three lessons from the history of science I specifically mentioned in the text. What are they?

3. Who was Imhotep?

4. Although the ancient Egyptians had incredibly advanced medical practices for their time, we do not consider them scientists. Why not?

5. Who were Thales, Anaximander, and Anaximenes?

6. Leucippus and his student, Democritus, are remembered for what idea?

7. Who championed the idea of spontaneous generation and is responsible for it being believed for so long?

8. Who came up with the first classification scheme for living creatures?

9. What is the main difference between the geocentric system and the heliocentric system? Which is correct?

10. What was the main goal of the alchemists?

11. Why don't we consider the alchemists to be scientists?

12. What was the main reason that science progressed near the end of the Dark Ages?

13. Who is considered to be the first modern scientist and why does he deserve that honor?

14. Two great works were published in 1543. Who were the authors and what were the subjects?

15. Although Galileo collected an enormous amount of data in support of the heliocentric system, he was forced to publicly reject it. Why?

16. Galileo built an instrument based on descriptions he had heard of a military device. This allowed him to collect a lot more data about the heavens. What did he build?

17. Who was Sir Isaac Newton? Name at least three of his accomplishments.

18. A major change in scientific approach took place during the Enlightenment. What was good about the change and what was bad about it?

19. What was Lavoisier's greatest contribution to science?

20. What is John Dalton remembered for?

21. What is Charles Darwin remembered for?

22. What does "immutability of species" mean, and who showed that this notion is wrong?

23. What is Gregor Mendel remembered for?

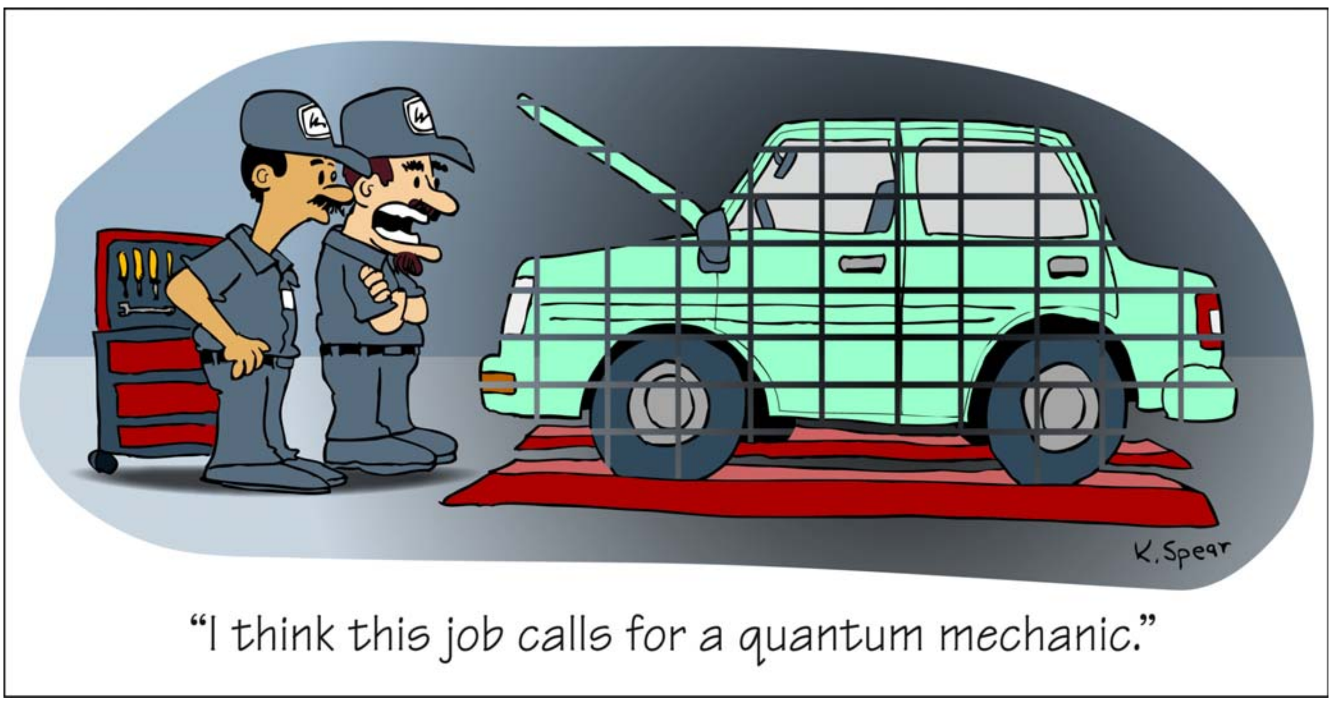
24. James Clerk Maxwell is known as the founder of modern _____________.

25. What law did James Joule demonstrate to be true?

26. What is the fundamental assumption behind quantum mechanics? Who first proposed it?

27. What is Niels Bohr remembered for?

28. Einstein was one of the founders of the quantum mechanical revolution. He also is famous for two other ideas. What are they?



Cartoon by Speartoons