apologia

EXPLORING CREATION WITH

GENERAL SCIENCE

3rd EDITION

Seligson

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THE HISTORY OF SCIENCE—SEARCH FOR THE TRUTH

Get ready for an exciting year! You might wonder why I know it will be exciting. Well, it is because we are beginning a study of the fascinating world of science. Before I go any further, let's discuss what science is. The word comes from Latin and simply means "knowledge." But today, the word *science* actually means much more. We can begin with a basic definition.

Science—The systematic study of the natural world through observation and experimentation in order to formulate general laws

FIGURE 1.1
Helium Balloons

Let me break that definition down for you. The end goal of science is found in the second part of the definition. *We use science to come up with general laws that help to explain what is going on in the world around us. Why, for example, do most things fall to the ground when you drop them, yet a helium balloon floats upward? Is there a general law to explain that?* Now, the beginning part of the definition

Quaestio

Why is a Latin word heading this section? Well, this course will be taking you through an overview of all of science, including its development and diversity. A major part of science involves asking questions and doing research. Look closer at those words: QUESTion and reSEARCH. Both words have elements of exploration, don't they? That is a large part of science: exploring the world around us to come up with general laws that God set in place to govern our world since the beginning of time. You will therefore be on a QUEST this year, SEARCHing through all facets of science. *Quaestio* is Latin for "question." Every module will start by reminding you that you are on a quest, searching the world for God's fingerprints. So basically, we'll be explorers together, on an amazing adventure!

explains how we come up with those laws. Scientists look at the world around them and collect facts about it. *Balloons filled with air will fall to the ground.* They also develop experiments to gather more facts. *What happens to balloons filled with other gases when they are released? How are air and those other gases different from helium?* That information is gathered in an ordered way to study and better understand our world. *When the weight of a helium-filled balloon is lighter than the amount of air it takes up, the balloon will float upward in the air.*

Now here is the really exciting part. Believe it or not, you have been a scientist from the day you were born. You have watched and listened to things around you. You learned how things felt, tasted, and behaved. As a baby, when you tossed items off a high chair, you were really exploring what we call gravity (even though that was a messy way to do it!). Then as a toddler, you went outside and examined grass, leaves, ants, and caterpillars. You watched it rain outside and studied the trickling of water as it ran down the window pane. And you were fascinated. That is what we are going to continue to do in this course. We are going to keep observing and experimenting to gather more knowledge with the purpose of better understanding the remarkable world that God created!

FIGURE 1.2
Young Scientist

THE EARLIEST SCIENCE: ANCIENT TIMES–600 BC

The best way to study how science works today is to learn about how it has developed throughout history. That's because the history of science will reveal how science should and should not be practiced. We will also learn where it is heading in modern times. So we will use this module to travel through time and observe the history of human scientific inquiry. That will allow you to better understand what science is and what it is not. First, let's travel way, way back to some of the earliest historical records.

Egypt

The first science records we have come from 3,000 years before Christ. Ancient Egypt is where we first see the dawn of what we would call medical care. Many Egyptian medical practices could cure illnesses. However, most of these methods came from trial and error. They would keep trying different things until something helped. If a method didn't work, the patient would have to suffer or even die, but the doctors would know not to use that method on the next patient. If the remedy *did* work, then they knew what to do the next time they saw that illness.

One of the physicians of that time, **Imhotep** (eem' oh tep) [c 2650 BC], was well known for his medical knowledge and ability to heal. People would travel hundreds of miles in the hope that he would be able to cure their illnesses.

Although the trial-and-error method of medicine sounds primitive, Egyptian doctors came up with some pretty successful treatments. For example, they learned that a good way to treat an open wound would be to cover it with moldy bread. That would make the wound heal quickly. Because it worked so well, doctors automatically would apply moldy bread to their patients' wounds. Can you imagine walking through an Egyptian doctor's office and seeing people covered with slices and strips of green, moldy bread? But, believe it or not, they were on to something. Today, we know that some bread molds produce penicillin, which is a chemical that kills the germs that infect wounds! So even though the Egyptian doctors knew *nothing* about germs, they still were able to treat open wounds by preventing them from getting infected.

FIGURE 1.3
Moldy Bread

Some people might see these slices of bread and think they should be thrown away, but Egyptian doctors saw their medical value!

The doctors also discovered a way to manage pain. If a patient was hurting, they would feed the patient seeds from the flowering poppy plant. Eating the poppy seeds seemed to bring pain relief. Again, the doctors didn't know *why* it worked. But modern science has shown us why. It turns out that poppy seeds have both morphine and codeine, which are pain-relieving drugs. In fact, they work so well, those drugs are used in medicine today.

One of the major reasons Egyptian medicine progressed so well as compared to the medicine of other ancient nations is that they invented **papyrus** (puh pye' rus).

Papyrus—An ancient form of paper, made from a plant of the same name

As early as 5,000 years ago, Egyptians took the pliable stems of the papyrus plant, sliced them into thin strips, laid them in a crosswise manner on top of each other, wet them, and then allowed them to dry. That resulted in a type of paper that they could write on and store.

Well, that enabled them to document information and send it from person to person. Up to that point in history, Egyptians, Sumerians, and other people groups wrote on clay tablets or on rocks. You can imagine that writing on rocks and clay and toting them around or storing them would be much more difficult. When Egyptians began writing on papyrus, that all changed. It could be readily rolled up into scrolls for easy transport or storage. That meant the knowledge of one scholar could be easily sent to other scholars. Their gained knowledge could accumulate and more easily be passed down to future generations. That helped to make Egyptian medicine the

FIGURE 1.4
Live Papyrus Plants

most respected form of medicine in the known world.

Other Cultures

But let's not leave out other cultures. They had some great inventions, too. At the same time papyrus was first used in Egypt, the Mesopotamians were employing the first known potter's wheel to make pottery. Horse-drawn chariots were being used as well. And as early as 1,000 years before Christ, the Chinese were using compasses to help them navigate. So we can say the ancient world was filled with inventions that transformed life during those times. These inventions are history's first beginnings of science.

FIGURE 1.5
Egyptian Pyramids at Giza

WHAT TO DO

Notetaking: One of the goals of this course is to help you learn to identify main points as you read information in order to get it "into your brain." Reading is only one way to do that. By writing down the important facts and definitions, you are giving your brain another way to review them and, therefore, you will better remember them. Plus, notetaking provides you with an easy way to review the module when it comes time for a test. Don't worry. I'll walk you through that step, too. The *Student Notebook* that accompanies this textbook is designed specifically to help you become comfortable with notetaking. Now, notice that there are 2 definitions in the previous section (science and papyrus). Words and their definitions (in bold and blue font) should be written in your notebook. You will need to memorize them. Your notebook is also designed to give you notetaking prompts. These will help you remember important information. Taking notes while you read your text will become easier with practice, and you will better recall what you have read.

"On Your Own" Questions: As we come to the end of this first section in the module, you might notice the rest of the module is divided up into other titled sections. At the end of each section will be one or more "On Your Own" questions. You should answer these questions (spaces for answers are in your *Student Notebook*) as soon as you come to them in your reading. You can look back at the module as well as your notes to find the information in order to answer the questions. These questions will help you to think about what you just read in the previous section to make sure you understand it. You will check your answer against the solution located at the end of each module in your textbook. If you got the answer correct, you are ready to move on. If you didn't get the answer correct, don't panic. Go back and reread the section of your textbook to try to understand the answer. You can also find additional materials on the textbook's Book Extras page. Make sure you understand the information before you continue your studies. Science builds on itself, so it is important to have a strong foundation.

Timeline: Finally, for this particular module only, we will be time-traveling through the history of science and meeting several notable scientists. Though you will not be required to memorize everything about all of them, you *will* be instructed to learn a bit more about a few. An important activity for this module will be to create a timeline, beginning at 3000 BC to AD 2000. This activity is found in your notebook. As you study each scientist, write his name under the date he lived and include one or more important facts you learned. For example, you learned about Imhotep in this section, so go ahead and add him to your timeline beneath the date 2650 BC. For this module, when I introduce a scientist from history, there will be a bracketed date after the name so you can place the scientist on your timeline.

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 as scientists. Why? (Hint: Look at the entire definition of science.)

TRUE SCIENCE BEGINS TO EMERGE: 600 BC—AD 500

The ancient Greeks are believed to be the first true scientists. Remember our definition of science. It is when observations and facts are gathered and are then used to come up with general laws about our world. So although the ancient Egyptians and Chinese had collected lots of observations and had recorded facts, they didn't go the next step to use those facts to develop explanations of the natural world. In fact, historians believe that didn't happen until the sixth century BC with the Greeks.

FIGURE 1.6 **Solar Eclipse**

A solar eclipse occurs when the Moon passes between Earth and the sun. The Moon either fully blocks or partially blocks the sun from view.

Three Greek Scientists

Three Greek scientists, Thales (thay leez) [640s–540s BC], Anaximander (an axe' uh man der) [c 500 BC], and Anaximenes (an axe' uh me' neez) [c 546 BC] are believed to be the world's first real scientists.

Thales studied the sky and tried to come up with a unifying theme to explain how the planets and stars moved. He was successful in predicting certain planetary events. In fact, he received notable recognition in his day for correctly predicting what he called the "short-term disappearance of the sun." This was a solar eclipse, which is when the Moon moves between Earth and the sun, blocking most of the sun from our view.

Historians believe Anaximander was one of Thales' students. He studied living organisms and is believed to be the first scientist to try to explain the origin of the human race without reference to a Creator. He suggested that all life began in the sea and at one time in history, humans were a type of fish. This idea was revived much later in history by some other scientists, including Charles Darwin (whom I will introduce in just a bit), and today is known as evolution. We'll discuss evolution later in the course and see what scientific data exist.

Anaximenes was probably an associate of Anaximander. He believed air was the most basic material in nature. He also believed that everything was made of air. So when air is thinned, he thought it would warm and turn to fire. When air is thickened, it would become liquid or solid material. Today, we know that those ideas are incorrect, but Anaximenes did try to explain all things in nature as being made of a single substance. That eventually led to one of the most important scientific ideas introduced by the Greeks: the concept of atoms.

Two More Greek Scientists

Another Greek scientist, **Leucippus** (loo sip' us) [early 400s BC], built on Anaximenes' thinking, and historians believe he proposed that all matter is composed of little units called atoms. Leucippus had a student, **Democritus** (duh mah' crit us) [460–c 370 BC]. Democritus' works are well preserved. He came up with a great analogy to help explain his ideas about atoms. Think about walking toward 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 to examine the sand, you see it is not solid at all. It is made up of tiny particles called sand grains.

FIGURE 1.7
Sand

Democritus noticed that from a distance the sand on a beach appeared to be connected like a smooth, solid blanket. But as the sand was more closely observed, it was evident that it was made up of small grains. This idea helped him to suggest that all matter was like sand, made up of small particles even though it appeared solid.

Well, Democritus thought that all matter was like sand. Even though it might appear smooth and solid, it is made up of very tiny particles called atoms. **It turns out that some materials in nature have atoms that are more tightly packed together than others.** That makes them behave differently from each other. Explore this idea more in Experiment 1.1.

WHAT TO DO

Before you begin any experiment, you should read **all** of the instructions to make sure you have the materials needed and understand what you will be doing.

EXPERIMENT 1.1
DENSITY IN NATURE

PURPOSE: To understand how atoms could explain things we see in nature

MATERIALS:

- A tall, clear canister or jar with a lid
- A ping-pong ball
- A 3-oz. lead sinker (the kind used for fishing)
- A bag of unpopped popcorn (small dried beans will also work)

QUESTION: What happens to 2 objects of different densities when they are in the same container?

HYPOTHESIS: Make sure you know what you think will happen to the less dense ball before you complete step 4 of this experiment.

PROCEDURE:

1. Fill the canister with popcorn so that it is about ¾ full.
2. Bury the ping-pong ball into the center of the popcorn so that it is just below the popcorn's surface. You should not be able to see the ping-pong ball; it should be completely covered.
3. Set the lead sinker on top of the popcorn and seal the canister.
4. Vigorously swirl the canister around and around in a circular motion from side to side and watch what happens to the balls. Use common sense when shaking so that your container does not crack.
5. Record in the lab notebook section of your *Student Notebook* what you saw.
6. Clean up and return everything to the proper place.

CONCLUSION: What happened to the ping-pong ball and the lead sinker when you swirled the canister?

Hypothesis

In the experiments for this course, you will be asked to come up with a hypothesis. A hypothesis is a statement describing what you think will happen in an experiment. You create a testable answer to a scientific question. One of the best ways to state a hypothesis is to write it as an "If-then" statement. It doesn't necessarily have be in this format, but it is a good way to help you plan your question and answer to a situation. For Experiment 1.1, for example, you might state, "IF 2 objects of different densities are in the same container and the container is swirled, THEN the less dense object will not sink as deep as the denser one." Or "IF the canister of popcorn is swirled, THEN both objects will sink to the bottom of the container." That way you can test your hypothesis to see if it is correct. An incorrect hypothesis does not mean the experiment was a bad experiment. Either way, you come out of the experiment learning something. The experiment tests your statement to see if your hypothesis is right. And that is good science!

What did you discover in the experiment? You should have noticed that the lead sinker disappeared and the ping-pong ball took its place. **Actually, the lead sinker sank down into the popcorn kernels and the ping-pong ball floated to the top.**

How is this experiment evidence for the existence of atoms? **Well, Democritus suggested that all things, including both objects, are made up of individual particles called atoms. The way those atoms are packed together will determine each object's characteristics.**

If you hold both objects in your hands, you should notice that one is heavier than the other. The 3-oz. lead sinker and ping-pong ball are not the same size. That means one object—the lead sinker—has atoms packed together more closely than the other. They are more densely packed, or in other words, that item has greater density. **Lower-density substances will always float on top of higher-density substances.** So the lead sinker sank down in the popcorn and the ping-pong ball floated to the top.

FIGURE 1.8
Mountain Lake

Everything you see in this figure is made up of atoms, including the solid sand, trees and mountains, the liquid water, and even the gaseous clouds and air!

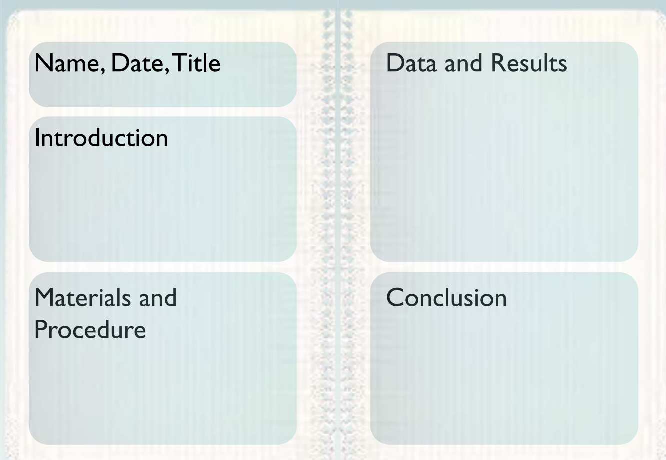
All substances, even liquids and gases, are made up of atoms. Some have tightly packed atoms while others have loosely packed atoms. If you imagine every substance to be made up of little grains (like sand), then the more tightly packed those grains are, the more massive the substance will be. Therefore, if you assume that atoms exist, then results of experiments like the one you just did are easy to understand.

Democritus was well ahead of his time. Today we know that all matter is made up of atoms. Scientists even know how distinct types of atoms are arranged in any given substance. That helps us to understand the concept of density. Democritus didn't get everything right, but he did believe that atoms were in constant motion, even in a solid substance.

WHAT TO DO

- ❒ **Create a formal lab report** with the headings Title, Introduction, Materials and Procedure, Results, Conclusion, on pages 413-414 in your Student Notebook.

FIGURE 1.9
Lab Report Sections for This Course



Now that you have completed this experiment, it is time to document what you have done. You will do this by **creating a formal lab report**. I will walk you through the process of a lab report during the first few modules so it will become very familiar to you (and very easy!).

Basically, a report shows what you did in the experiment and what you learned so that someone who has never done this experiment would understand what happened and why. It is always written in the third person. That means you do not use personal pronouns, such as "I," "we," or "you."

For this experiment, you need to write your name, date, and experiment **Title** on the top of the page. The next section will be the **Introduction**. In it you will write a short sentence or 2 explaining why this experiment is being performed, along with your hypothesis, or what you think will happen before you swirl the canister and why.

Next, write about your **Materials and Procedure**. In this section, you will list the materials you used in sentence form, if possible. Then you will explain in a few simple sentences what you did. You might also want to make an illustration showing the setup.

The next section will be your **Results**, or what happened when you did the experiment. Here, you can also add a sentence or 2 to discuss why you think you got the results you did.

The last section is your **Conclusion**, or what you learned.

To help you figure out what to write, I highlighted key sentences in orange before and after the experiment to give you clues for your hypothesis, results, and conclusion. You should be able to explain what you thought would happen (for the Introduction) and what you did (for the Materials and Procedure). But *please* be sure to write your sentences using *your own* words. Copying someone else's words is plagiarism, and that is not allowed. If you're having a hard time doing that, try to tell your parents or a sibling what you did. Then write down what you said to them.

A sample formal lab report for this experiment is at the end of this module on page 29. For each module, I recommend you choose one of the experiments and do a formal lab report. Writing one per module will be good practice for the scope of this course. Your *Student Notebook* has a space to write your report.

EXPLORE MORE

Fill one glass with very hot water and another glass with very cold water. Then add a single drop of food coloring to each glass. Watch how the color gets distributed in the water. In which glass does the color spread out faster? It turns out that atoms move faster when a substance is hot, so the glass filled with hot water will distribute the food coloring much more quickly. The cold water will eventually distribute the color as well. Both have atoms moving around, but some move more rapidly than others.

Even More Greek Scientists

Let's now go back to our science time travel and look at the lives of 3 other notable Greek scientists. You might have heard of the first one: **Aristotle** [384–322 BC]. He is called the father of life sciences. Born shortly before Democritus died, Aristotle wrote volumes of works on philosophy, mathematics, logic, and physics. However, Aristotle's greatest work was the study of living things. In fact, he was the first to come up with a system to classify animals and plants, placing them into groups based on their similarities.

Although Aristotle was a respected scientist, he also was responsible for some incorrect ideas that hampered science for many, many years. An example of that is his belief that certain living organisms spontaneously formed from nonliving substances. This idea is called spontaneous generation.

Spontaneous generation—The idea that living organisms can be spontaneously formed from nonliving substances

Spontaneous generation is how some scientists thought maggots (young flies) spontaneously formed from rotting meat. They believed that rotting meat left out for a few days would actually *transform* into maggots.

FIGURE 1.10
Dead Fish

Scientists who accepted spontaneous generation believed that rotting meat, such as this fish, would transform into living maggots. Yet today we know that flies lay their eggs into rotting meat, and the young larvae (maggots) hatch there.

Today, of course, we know that spontaneous generation is impossible. In fact, in all our observed experiences, life can only be formed by the reproduction of other living things. We will go into greater detail about this topic in a later module, but the lesson for us right now is an example of how science should *not* be done. Though Aristotle made great advances in the study of living things, he mistakenly believed in spontaneous generation. And because he was so well respected (rightly) as one of the greatest scientists of his time, spontaneous generation was believed to be true for over 2,000 years after he came up with it!

think about this

Wrong reasoning can lead to wrong science. There are many possibilities for wrong reasoning, sometimes called fallacy, in science. Sometimes a person makes a general conclusion about a subject, but only has a few cases on which to make that conclusion. An example of this hasty generalization is if, after cutting your foot on a shell at the beach and observing that the same thing happened to your friend, you might generalize that "This beach is full of sharp shells that will always cut a person's feet." This is why scientists need large sample sizes to make conclusions about what they observe. Another type of wrong reasoning is when a person assumes something causes an event just because it happened before the event. For example, a baseball pitcher might be chewing a new brand of gum while he pitches his first no-hitter. He might be tempted to say that the new brand of gum was the cause of his perfectly pitched game.

Archimedes (ark uh me' deez) [c 287–c 212 BC] is the next Greek scientist I will talk about. He lived about 100 years after Aristotle and did great work in mathematics, using much of that work to forward science. In fact, he applied mathematical formulas to explain why certain things happened the way they did. The Fields Medal is awarded every 4 years to recognize outstanding mathematical achievement. The medal's image is of Archimedes, and the inscription translates as "Rise above oneself and grasp the world."

FIGURE 1.11
The Fields Medal

The last Greek scientist I want to talk about lived about 100 years after Christ's birth. **Ptolemy** (tahl' uh mee) [c AD 100–170] studied the heavens and was one of the first to attempt a complete description of the planets and stars. He assumed that Earth was at the center of the universe, and that the planets and stars orbited about Earth in a series of circles.

In his day, there was lots of evidence to support Ptolemy's hypothesis, so his idea became very popular. This view of the stars and planets is called the **Ptolemaic system,** or the **geocentric system.** It was accepted by scientists until about the 1600s. This incorrect idea was accepted for so long because even as more and more data were collected that contradicted the geocentric system, many scientists ignored the data out of great reverence to Ptolemy because he was a great scientist. It also fit many scientists' preconceived notions of how things *ought to be*. They liked the idea of Earth being the center of the solar system, so the geocentric system made sense to them, even though there was more and more data to disagree with it.

FIGURE 1.12
Illustration of the Geocentric System

This illuminated illustration shows Earth in the center of the solar system with the Moon and planets orbiting it, as Ptolemy suggested. It was illustrated by Portuguese cosmographer and cartographer Bartolomeu Velho.

Aristotle and Ptolemy's stories can teach us something. A scientist shouldn't hold onto an idea just because it fits some preconceived notions. And a scientific idea should not be accepted just because a brilliant scientist believes it. Science is built on data that are tested time and time again, not on a person's beliefs.

ON YOUR OWN

1.2 Based on your results in Experiment 1.1, what do you think about the density of popcorn kernels? Are they more or less dense than the lead sinker and the ping-pong ball?

1.3 Albert Einstein is one of the most well-known scientists in recent history. (We'll talk more about him later in this module.) Though he received the 1921 Nobel Prize for his contributions to theoretical physics, he also had some ideas that were incorrect. Einstein believed that it would be a very long time before nuclear power would ever be a good source of usable energy. Yet his own groundbreaking equation, $E = mc^2$, is at the heart of over 400 nuclear power stations today, providing a major source of worldwide non-carbon-based energy. Imagine what would have happened if scientists decided not to explore nuclear energy because Einstein, a brilliant scientist, said it wasn't worth exploring. Name one more example of a brilliant scientist who advanced an incorrect idea. What do these examples teach us about how to make scientific decisions?

SCIENCE PROGRESS STALLS AND THEN GETS MOVING AGAIN: AD 500–1500

After the time of the highlighted Greek scientists, science continued to progress steadily. Scientists were exploring ways to study and explain the natural world. Scientific communities formed, referencing and utilizing the works of previous scientists like Aristotle.

But something happened. After the first few centuries AD, scientific progress drastically slowed. This was at the same time the Roman Empire reached its height and was beginning to decline. You see, although the Romans embraced inventions, particularly those that improved the processes of work, there was little desire for *explaining* the world around them. So real experimental science was discouraged throughout the known world. This era is known as the Dark Ages.

Alchemy

Alchemy, on the other hand, grew during the Dark Ages. The main goal of alchemists was to find a way to transform lead (or other inexpensive metals) into gold (or other precious substances). They were doing this because by that time in history, many people observed that when you exposed some substances to each other, they changed into other substances.

EXPERIMENT 1.2

A CHEMICAL REACTION

PURPOSE: To determine what can happen when you mix specific substances together

MATERIALS:

- A fresh lemon
- A small knife
- 3 tarnished pennies (The more tarnished, the better your results will be. Pennies minted between 1962 and 1982 work well for this experiment, as they contain 95% copper and have been in circulation long enough to build up a good coating of copper oxide.)
- A paper towel
- A paper plate
- A teaspoon of salt
- An eyedropper
- Some water

QUESTION: What happens when copper pennies are exposed to lemon juice?

HYPOTHESIS: (A hypothesis is what you think will happen and why.) Write what you think will happen to a penny when it is exposed to lemon juice.

PROCEDURE:

1. Using the knife, carefully cut a few small slits through the lemon peel. You want to cut all the way through the peel.
2. Insert a penny into each slit so that half of the penny is exposed to the juicy inside, not just the peel.
3. Allow the pennies to sit for at least 10 minutes.
4. Remove the pennies, dry them with the paper towel, and note their appearance.
5. Rinse the pennies and place them on a paper plate.
6. Sprinkle a small pile of salt on top of each penny. With the eyedropper, add a few drops of water to cover each penny.
7. Allow the pennies to sit for a few minutes and then blot them with a paper towel so the pennies are exposed to air. Let the pennies sit overnight.
8. Observe the colors of the pennies and write what happened in your notebook.
9. Clean up and return everything to the proper place.

CONCLUSION: What did you observe? What happened to the part of the penny that was exposed to lemon juice?

In the first part of the experiment, you should have noticed that the halves of the pennies exposed to the inside of the lemon turned a bright copper color. That is because the original copper in the tarnished pennies had combined with the oxygen in the air to make a chemical compound called copper oxide. The acid of the lemon juice caused a chemical reaction, causing the copper oxide to break the copper atoms and the oxygen atoms apart, so you could see the shiny copper color.

In the second part of the experiment, you exposed the pennies to salt and water. This caused another chemical reaction to occur by helping the copper in the pennies to react again with the oxygen in the air. So the next day, you should have noticed that the pennies were starting to tarnish again.

Alchemists saw changes like the changes you observed in the previous experiment and thought that if they could find just the right combination of substances, they could mix a metal such as lead with several other substances so it would change to gold. Today, we know this is impossible because there are severe limitations to how much a substance can actually change within a chemical reaction. However, the alchemists didn't know this, so they used trial and error to see if they could stumble upon the perfect mixture to make precious gold out of commonplace lead.

FIGURE 1.13
Medieval Gold Coins

However, they *did* keep records of their work, and as a result, many interesting observations were recorded. Sometimes, one of the mixtures would actually form a useful substance, too. But they never tried to use their observations to draw conclusions about how the natural world works. They just kept trying to make new substances out of existing ones.

The events during this time period can teach us 2 things about science. A stalling of science happened during the time of the Roman Empire's decline. With hampered trade and communication, scientific progress slowed. So, lesson 1 is that **scientific progress depends not only on scientists, but it also depends on government and culture.** And lesson 2 is that **science progresses by building on the work of previous scientists.**

Other Medieval Cultures

Now, other cultures were also exploring the world during this time period. The Arabs and Chinese were making careful observations of the heavens and logging their observations, but (like the Roman scientists) not trying to explain what those data meant. The Chinese noted in AD 1054 the sudden appearance of a bright star. Because their data were written down, future scientists *could* use it to compare to what they saw in the skies and make conclusions. In fact, modern scientists believe the Chinese were observing a supernova, which is essentially the explosion of a star. That is because in the same part of the sky today, there is a large cloud of dust and gas, called a nebula. So scientists used recorded evidence along with modern evidence to suggest that a supernova results in a nebula. These scientists built on the work of scientists who came before them.

FIGURE 1.14
The Crab Nebula

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

EXPLORE MORE

How many dimes does it take to have a mass of 2 oz? Well, you could grab a kitchen scale and a handful of dimes and place them one by one onto the scale until it read 2 oz. But what if you had access to some previous observations made by a scientist? What if you read his documentation that said he determined it takes 12 dimes to have a mass of 1 ounce? You could use that information to further your experiment. If it takes 12 dimes to have a mass of 1 oz, you could start with 12 already on the scale and go from there. Or you could realize that if you doubled that amount to 24 dimes, you would also have double the mass, or 2 oz. Can you see how science can progress by building on the work done by previous scientists? Try measuring dimes to explore this.

End of the Dark Ages

By about AD 1000 Christian scholars began to realize that their belief in a single God who created the universe would have set up specific universal laws to govern it. They believed God's laws never changed, so therefore the natural laws God set into motion should also never change. As a result, the way the natural world worked could be explained if they could discover the natural laws God set in place. Therefore, science began to progress toward the end of the Dark Ages because the Christian worldview began to replace the Roman worldview.

This thinking caused real science to emerge again. Some of the notable scientists of this era include **Robert Grosseteste** (groh' suh test' ee) [c AD 1175–1253]. He taught that the purpose of inquiry was not to come up with random experiments and the observation of their results, but to learn the *reasons* behind those observations, instead. That is really what science is: explaining why things happen the way they do. So Grosseteste is known for coming up with the first ideas behind the scientific method and is often called the father of the scientific method. He believed a scientist should make observations, and then come up with a tentative explanation for why those events happened. Then he should make more observations to test that explanation. If the new observation didn't agree with the original explanation, then the new explanation was probably wrong.

One of Grosseteste's followers, Roger Bacon, is even more well known [c AD 1219–c 1292]. Bacon was known for strongly encouraging scientists to use Grosseteste's method, so sometimes people wrongly call Bacon the father of the scientific method. He was known to use science to break superstitions. One example was the conventional belief that diamonds could be broken by goat's blood. He came up with experiments to prove that idea to be wrong. Bacon was a visionary, believing that science could eventually bring about flying machines, explosives, submarines, and the ability to travel around the world!

FIGURE 1.15
World Map with Modes of Transportation

Roger Bacon's ideas of world travel were hundreds of years ahead of his time. It wasn't until the 1600s that a working submarine was built, and the airplane wasn't invented until 1903.

In the early 1300s, Thomas Bradwardine (brad war' deen) [c AD 1290–1349] began work on 2 levels. Bradwardine was a theologian and emphasized salvation by faith alone, through the grace of God. But he also is important in the development of modern science. He was one of the first to critically examine many of Aristotle's ideas and found most of them lacking. Focusing on motion, he came up with equations to try to describe the details of speed, distance traveled, and more. Using mathematics and experiments, he showed that most of Aristotle's ideas about motion were wrong.

Nicholas of Cusa [AD 1401–1464] was interested in the idea that God was infinite. In trying to learn more about God's infinite nature, he studied the planets and stars because he thought they were the largest and most infinite things he could study. He was one of the first scientists to break from Ptolemy's geocentric view and believe that the Earth spins on its axis while it travels around the sun.

ON YOUR OWN

1.4 Explain why it is important to document scientific data.

1.5 Some people believe that science and Christianity are at odds with one another. That idea has developed because in recent years, many scientists are not Christian. Explain how a Christian worldview is, in fact, one of the reasons science got out of the Dark Ages.

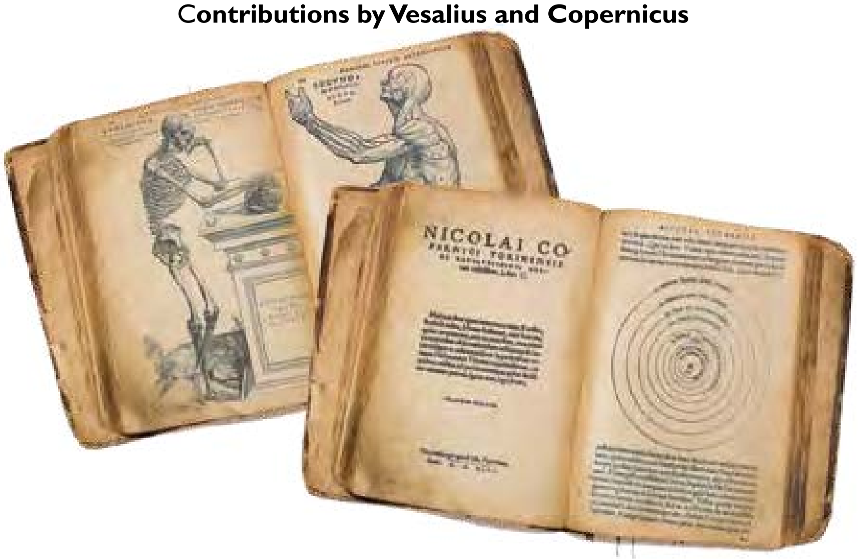
Have you noticed that many of the great scientists since the 1000s were devout Christians? In fact, as we go through the rest of this module, you will see that many of the great scientists from the Dark Ages to modern time were devoted Christians. That is because the Christian worldview is a perfect fit with science!

THE RENAISSANCE—THE "GOLDEN AGE" OF SCIENCE: AD 1500–1660

As we enter this time period, we will discover that it is a time when science blossomed. Though lots of amazing discoveries were made about the world by many, many scientists, we will highlight 5 in this section. It begins in 1543 when 2 important works were published. The first was by **Nicolaus Copernicus** [AD 1473–1543]. In it, he laid out his idea about Earth, the sun, planets, and stars. Just like Nicholas of Cusa, Copernicus believed that Ptolemy's view of the universe was incorrect. He instead believed the data he had were better explained if the sun was in the center of our planetary system and all the planets, including Earth, orbited around it. This is known today as the heliocentric (he' lee oh sen' trik) system or the **Copernican system** in his honor.

The other important work published in 1543 was written by a doctor named **Andreas Vesalius** (vuh sal' ee us) [AD 1514–1564]. It contained the most detailed and amazingly accurate illustrations of the human body. In fact, this was the first book to illustrate all of the insides of the body, including the organs, muscles, and skeleton.

FIGURE 1.16
Contributions by Vesalius and Copernicus



In 1543, both Vesalius and Copernicus published works to help "map" things within their respective fields. Vesalius illustrated the arrangement of the organ systems within the human body, and Copernicus used scientific data to explain how the solar system was arranged. Both systems showed God's perfect order in His design.

Vesalius's book was recognized right away as revolutionary to medicine, but Copernicus' book was not so well received. That's because the church of that time believed the idea of Earth being at the center of everything made more sense. They did have a point in that Copernicus did not have lots of data to support his ideas. He promoted the heliocentric system because he knew there was lots of evidence *against* Ptolemy's geocentric system. Copernicus also thought that God fashioned the heavens using the heliocentric system because it was the more orderly and pleasing of the 2.

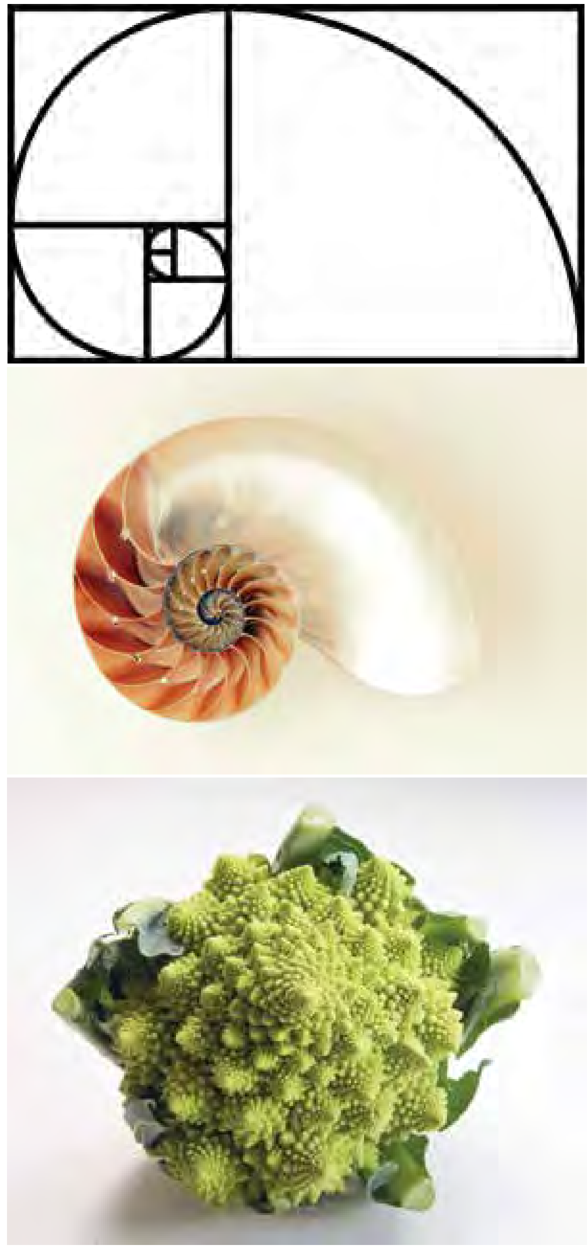
As more evidence was compiled, Copernicus' heliocentric view became more readily accepted. One of the most important compilers of that evidence was **Johannes Kepler** [AD 1571–1630]. He wanted to bring glory to God as he studied the heavens. Kepler's detailed observations of the planets helped him to deduce the basic orbits that the planets use to travel around the sun. He could even describe the orbits mathematically.

In fact, his mathematical equations were known as Kepler's laws and became one of the most powerful arguments for the heliocentric system. He could even deduce that planetary orbits were more elliptical, not circular.

A fourth notable scientist who lived in this era is **Galileo** (gal uh lay' oh) **Galilei** (gal uh lay') [AD 1564–1642]. Galileo performed detailed experiments about motion, supporting Bradwardine, and identifying the flaws of Aristotle's thinking. Using designs for a military device, Galileo built a telescope made from a tube with 2 lenses that could greatly magnify distant objects. Though he is not the inventor of the telescope, Galileo greatly improved its design. He was able to compile details about the planets and stars, showing that the planets shone in the sky not because they generated their own light, but by reflecting the light of the sun. This and other facts made it clear that the heliocentric view was superior to the geocentric view.

Blaise (blayz) **Pascal** (pas kal') [AD 1623–1662] was a philosopher, mathematician, and scientist. He is known for making great advances in the study of geometry and algebra. You can thank Pascal for your high school math classes! Additionally, Pascal studied how fluids behave and also demonstrated that the air we breathe exerts pressure on everything, an effect called atmospheric pressure.

FIGURE 1.17
The Golden Spiral



Mathematics play a key role in understanding many scientific phenomena. In geometry, a golden spiral is a spiral whose growth factor increases by a specific amount for every quarter turn it takes. This mathematical principle can be seen in several living organisms, both plant and animal.

EXPLORE MORE

Pascal explained that air is constantly pushing against everything, exerting pressure. Try this quick activity to explore air pressure. Take a drinking glass and fill it one-fourth to one-third full with water. Cover the mouth of the glass with a piece of card stock, making sure the card completely covers the glass. Hold the card in place with your hand flat on it as you turn the glass upside-down *over a sink*. Some water might leak out, but hold the card in place making sure it makes complete contact with the entire rim of the glass. Remove your hand from the card. What happened? The card should stay in place. That's because the pressure of the air pushing up on the card is stronger than the weight of the water and the resulting lack of air pressure pushing down on it from inside the glass (called a vacuum). The card experiences about 15 lb of force pushing upward by the air, but only 1 lb of force pushing downward from the water. Air pressure can be a powerful force!

ON YOUR OWN

1.6 Galileo is often incorrectly credited with the invention of the telescope. Look back in this section to see *exactly* what his contribution to the telescope was. Explain how this is an example of the importance of documenting scientific data and sharing that documentation with other scientists.

THE ERA OF NEWTON: AD 1660–1735

This era of time continues in the footsteps of the golden age of science, but even though there were many scientific discoveries by several great scientists, we are going to focus on only 3. And one of those 3 took center stage. That is because science experienced the greatest advancement during the time of **Sir Isaac Newton** [AD 1643–1727]. Newton was a devout Christian, like many of the great scientists you have already studied. He studied science specifically as a means of learning more about God, and he also believed that the best way to learn about God was by studying the Bible. Newton wrote most of his revolutionary scientific works in a 3-volume set called *Principia* (prin sip' ee uh). The first volume explained Newton's 3 laws of motion. In it he made a direct link between mathematics and science, saying that a scientific law was useless if it did not have a supporting mathematical equation to describe some aspect of nature. That was a major breakthrough for the science of the physical world, transforming it into a rigorous field of study.

The second volume of *Principia* built on the work of Pascal and focused on the motion of fluids. The third volume included Newton's universal law of gravitation. He showed, using detailed experiments, that gravity was responsible for attracting objects to Earth (making them fall) as well as keeping planets in orbit around the sun. Because of his mathematical equations that supported these ideas, his third volume was the last blow to the geocentric view of the heavens.

Robert Boyle [AD 1627–1691] is known as the founder of modern chemistry. He lived at the same time as Newton, performing experiments on gases and formulating laws that are used today in the study of chemistry. He was a dedicated Christian, often writing materials and sponsoring sermons that used nature to give glory to God.

Another notable scientist from this period was **Antoni** (an' ton ee) **van Leeuwenhoek** (loo' en hook) [AD 1632–1723]. Though he was not educated as a scientist, he revolutionized the study of living things by building the first high-powered single lens microscope. That opened science up to a previously unseen world of tiny life forms, including bacteria. And like Boyle, Leeuwenhoek tried to glorify God in all his scientific work. The microscopic world was testimony to him that God made all creatures, great and small.

FIGURE 1.18
Replica of a Microscope Design by Leeuwenhoek

ON YOUR OWN

1.7 Some students think learning mathematics is difficult. 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?

THE "ENLIGHTENMENT" AND THE INDUSTRIAL REVOLUTION: AD 1735–1820

Why is the word *enlightenment* given quotation marks in this section title? Well, during this period in history, a change in the underlying assumptions of science and how to look at the world occurred. A philosopher who lived during this time, Immanuel Kant, came up with the term *enlightenment* to describe the change because the word means "to gain knowledge." However, the title word is in quotation marks because that change was only *partly* beneficial to the progress of science.

FIGURE 1.19
Medieval Cross

What is this notable change? For many people, there was a rejection of things from the past, such as religion and monarchies, and there was an emphasis on reason, liberty, and the scientific method. So some of the change in thinking had to do with how people believed the universe came to be. Up to this point in history, God was at the center of virtually all science. In most of the previous sections, the great scientists I have been highlighting were devout Christians. That means that until now, science had a very Christian flavor, with the scientists endeavoring to see God's creative fingerprints in creation and mentioning God reverently in their scientific papers.

Since the Dark Ages, advances in science were the result of scientists questioning the teachings of Ptolemy, Aristotle, and other scientists whose works had dominated science for so long. That meant the scientific community was learning that scientists shouldn't just blindly accept the teachings of former scientists. They realized, rightly so, that all scientists make mistakes, and therefore everyone's work should be critically examined. To sum up, **science stopped relying on the authority of past scientists and began relying on experiments and data.**

Well, that is actually a good change that happened during the Enlightenment. All scientific works *should* be carefully examined. Unfortunately, though, **as science began to ignore the authority of past scientists, it also began to ignore the authority of the Bible.** And that is a bad result of the Enlightenment. So even though a biblical worldview fueled the science of the past, some scientists in this era started to question the truth of the Bible.

There were still some scientists who were devout Christians during this time, but as time went on, fewer and fewer references to God and the Bible could be found in scientific works.

One of the notable Christian scientists during this time is **Carolus** (kair' uh lus) **Linnaeus** (lih nay' us) [AD 1707–1778]. In 1735, Linnaeus published a book in which he created a classification scheme that categorized all living creatures that had been studied. The basic classification he came up with is still in use today. Now, Linnaeus was deeply committed to performing science as a way to glorify God. He believed that God is very organized, so His creation should also be organized.

FIGURE 1.20
Rothschild Giraffe

The Rothschild giraffe is found mainly in Uganda and Kenya. According to today's modern classification system, based on Linnaeus' major scheme, it would be classified in kingdom Animalia, phylum Chordata, class Mammalia, order Artiodactyla, family Giraffidae, genus *Giraffa* and species *camelopardalis*. The Rothschild giraffe would then be placed into a smaller category: subspecies *rothschildi*.

Antoine-Laurent (an twon' law rent') **Lavoisier** (luh vwah' see ay) [AD 1743–1794] was a chemist who analyzed chemical reactions in a systematic way. His most important contribution to science was the law of mass conservation, which stated that matter cannot be created or destroyed—it can only change forms.

John Dalton [AD 1766–1844] also lived during this time period. A devout Quaker, he did many experiments with gases and came up with many new ideas that propelled science forward. One of his most important works was his atomic theory. He built on the works of Democritus and others, proposing a detailed theory of atoms. He is known as the father of modern atomic theory.

This period is also known as the Industrial Revolution because it was a time when the growing scientific knowledge gave rise to a rapid increase in inventions that made work faster and more productive.

EXPLORE MORE

During the Industrial Revolution, many devices were invented that turned hours of manual labor into just a few minutes of work. Even today, robotic machines do in minutes what used to take days. You can make a simple robotic hand using materials in your home.

You will need 4 drinking straws, scissors, a stapler, a ruler, masking or cellophane tape, and about 5 feet of string. If your straws have bending ridges, do the instructed work on the opposite end. Bend the straw at about one inch from the end and carefully cut off one corner of the bend. That should give you a diamond-shaped hole. Do the same thing at 2 inches and 3 inches from the straw's end so that the holes are lined up. Repeat with the other 3 straws. Cut your string into 4 equal lengths. Thread one length of string through a straw so that about 1–2 inches are sticking out of the end closest to the holes. Staple over the string and straw and tie a double knot in the string so it won't slip through the staple. Do the same thing for the other 3 straws. Now lay the straws beside each other so that the diamond-shaped holes are facing upward. Tape the straws together. Gently bend the straws upward at each hole to form a crease on the straw. This will form a finger joint. Now pull on all 4 ends of the string so that the "fingers" bend. Can you grab anything with your mechanical hand?

THE REST OF THE 19TH CENTURY: AD 1820–1900

The rest of the 19th century was filled with advances in science, partly due to the fact that people began to appreciate science more than ever before. They could tangibly see how inventions could make their lives better, and that translated to more financial support for science.

One of the most notable scientists during this period is Charles Darwin [AD 1809–1882]. He published a book in 1859 titled *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*, which is often shortened to *The Origin of Species*. This book caused an upheaval within the scientific community. In it, Darwin proposed a theory that tried to explain the diversity of life on Earth and how it came to be without a Creator. He proposed that the same kinds of processes we see occurring today are responsible for all the species on the planet. This is commonly known as the theory of evolution.

You will learn a lot more about Darwin and his theory later in this course and even more in-depth when you study biology. But for now, you need to understand the impact of his work on the progress of science. First, Darwin's ideas were the final development of the Enlightenment. So those who wanted to ignore the authority of Scripture were empowered. 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?

The second impact of Darwin's work was to improve the study of living things dramatically. Now, let me stop here to say that I, as well as many, many other scientists today, think that Darwin's idea of evolution is fundamentally incorrect. Yet, even wrong ideas can help advance science. You see, before the time Darwin published his writings, scientists thought that every type of creature that exists today had existed throughout history. Consider dogs, for example. Up to this time, scientists thought that Great Danes, chihuahuas, and boxers always existed, unchanged through history. That idea is called the **immutability of the species.** But Darwin showed it wasn't true. He had evidence of how living organisms can adapt to changes in their surroundings through a process he called **natural selection.** So over time, an organism would change in its coloring, beak size, body size, and other physical characteristics. That resulted in new versions of old creatures. In our dog example, the original dog breed spread out to different areas of the world and was exposed to various environments. Those in colder climates, for example, would have longer fur because puppies born with short fur wouldn't survive long enough to reproduce. Nature "selected" which features were beneficial. In the same way, breeders would choose the best puppies in a litter that had the features they were looking for, whether it was physical features or even temperaments, and then only allow those to breed. Breeders "selected" which features were beneficial. Over generations, those processes produced the breeds we see today.

FIGURE 1.21
Various Dog Breeds

The first created dog was likely a mutt in its design. As individuals spread to different parts of the world and were exposed to different living conditions, those with physical features that helped them better survive were able to live longer and pass those features on to their puppies. The same thing happened as man selected specific desirable features in domesticated dogs, only allowing individuals with those features to breed.

Another scientist who produced revolutionary work is **Louis Pasteur** [AD 1822–1895]. He came up with experiments that finally destroyed the idea of spontaneous generation once and for all. In a sense, his contemporary—Darwin—was trying to suggest that life came from nonlife, without God. That is technically a type of spontaneous generation, isn't it? But Pasteur demonstrated that life could only originate from other living things.

FIGURE 1.22
Pasteurization Equipment

Pasteur also came up with the process called **pasteurization,** a method to prevent bacteria from spoiling liquids. He used it to keep wine from souring, but today this process is widely used to sterilize milk. Additionally, Pasteur laid the foundation of vaccines.

Gregor Mendel [AD 1822–1884] lived during this time period. An Augustinian monk, he was a devout Christian who devoted much of his life studying reproduction in plants. In fact, the entire field of genetics, which studies how traits are passed on from parent to offspring, is based on his work. He is considered the father of modern genetics.

Science also experienced development in the understanding of electricity and mag-

FIGURE 1.23
Electric Light Bulb

netism. Michael Faraday [AD 1791–1867] performed many experiments about electricity, and his ideas are still used today. A devout Christian, Faraday was not ashamed of his faith and would argue with any scientist who tried to refute a belief in God. His faith actually led him to lay the foundations of the work of the next scientist we will highlight, James Clerk Maxwell [AD 1831–1879].

Maxwell is considered the founder of modern physics. He worked with Faraday and was interested in Faraday's belief that nature was interconnected at a fundamental level, because he believed nature derived its characteristics from God. So Faraday thought electricity and magnetism were the result of a single process, though he couldn't find evidence for it. Maxwell was able to develop mathematical equations to show Faraday was indeed correct. Electricity and magnetism are both different aspects of the same phenomenon called electromagnetism. This is a great example of what can be accomplished when you allow your science to be guided by a biblical worldview.

The last scientist we'll highlight in this time period is James Joule [AD 1818–1889]. He built on Lavoisier's ideas and determined that, like matter, energy cannot be created or destroyed but just changes forms. This is known today as the First Law of Thermodynamics.

ON YOUR OWN

1.8 In this section, you learned about Louis Pasteur, whose experiments dealt a final blow to the idea of spontaneous generation. Today, all scientists agree that spontaneous generation cannot occur. Explain how that fact is a problem for Darwin's idea that life came to be on Earth without God creating it.

MODERN SCIENCE: AD 1900–PRESENT

At the turn of the century from the 1800s to the 1900s, there were scientists who believed that science had discovered almost all there was to discover about nature. By this time, they could chart the planets in their courses, and they knew a lot about stars and visible space. Volumes were written about the microscopic world, and the classification of all known organisms was finally being completed. Thanks to Mendel and others, scientists were understanding the complex process of reproduction, too. Maxwell led the way for electromagnetism to be described. Newton's laws of motion seemed to explain almost every type of motion that could be studied. What else could there possibly be to learn?

Well, in 1900, Max Planck [AD 1858–1947] came up with a revolutionary idea. He suggested that in the same way that matter exists in small packets called atoms, energy exists in tiny packets, too. He called these packets quanta. Up to this point, scientists believed that you could give any amount of energy to an object. But Planck proposed that if energy came in packets, you could give 1 packet of energy to an object or 2 packets of energy to an object. But you could not give an object any amount of energy between one and 2 packets. The same way you could not have 1½ atoms, you could not have 1½ packets of energy. Now, Planck had lots of evidence for his idea, and after a long time, it became accepted by the scientific community. The study of this field of science, in fact, is called quantum mechanics.

One of the most famous scientists in the field of quantum mechanics is likely someone you have heard of. Albert Einstein [AD 1879–1955] used Planck's idea of little quanta of energy to explain a problem that scientists couldn't figure out. The photoelectric effect couldn't be explained up to this point if he used Newton's laws of motion, but if he used Planck's energy quanta, it could. The photoelectric effect has to do with the release of small parts of the atoms in a substance when light is shone onto it.

To add more evidence to support this effect, Neils Bohr [AD 1885–1962] developed a picture of what an atom looks like. It was based on solid mathematics, and it required the assumption that energy comes in small packets. The Bohr Model of the atom revealed many mysteries of what atoms looked like and were made of.

Now, let's jump back to Einstein before we end this module. He is an important figure in many other areas of science. He developed a new way of looking at light, matter, and gravity. His special theory of relativity explained how matter is just another form of energy. Using his now famous equation, $E = mc^2$, he showed how matter could indeed be converted to energy. His general theory of relativity explained how gravity works.

The knowledge gained from quantum mechanics and relativity has led to numerous advances in medicine, technology, and industry. In many ways, they have made life easier for everyone. Peo-

FIGURE 1.24 Young Albert Einstein

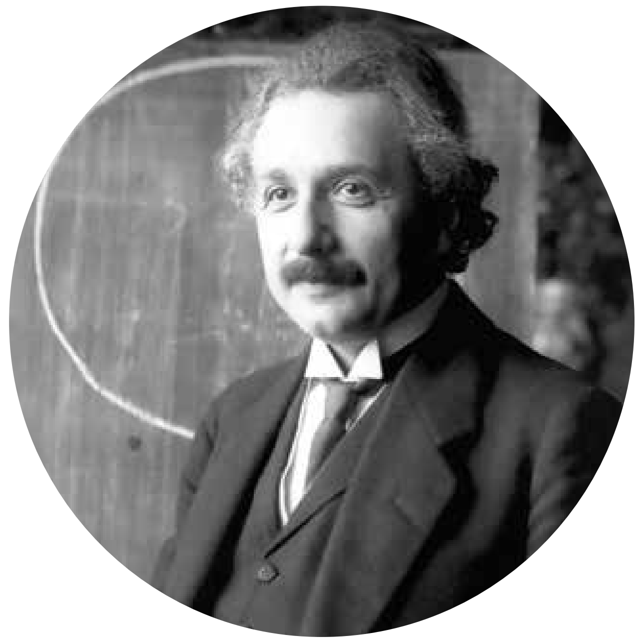
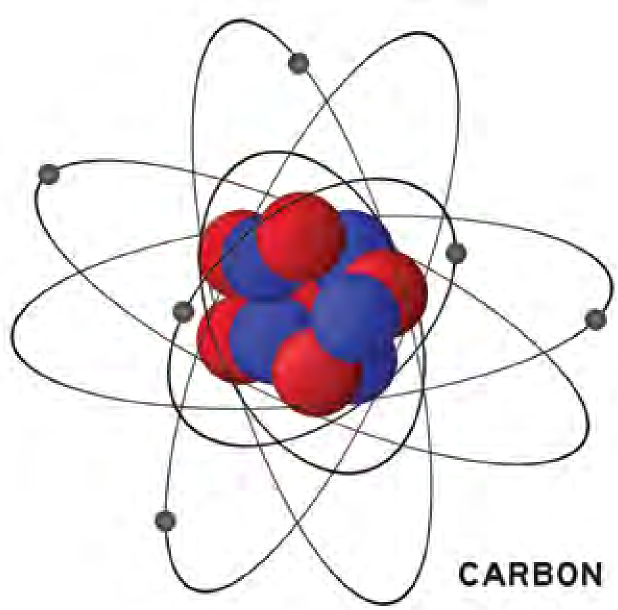


FIGURE 1.25
Bohr Model of a Carbon Atom



ple live longer today; there are fewer diseases, and there is more food per person today than ever before. Also, we have a clearer picture of how creation works. But don't be like the people at the turn of the century before the 1900s and think we have "figured it all out." Science is constantly uncovering new ideas and new ways of looking at things. That's what makes science so fascinating!

SUMMING UP

Well, we've come to the end of the module. Is your head spinning a little? Well, I wouldn't be surprised. After all, we have traveled through 5,000 years of science history. Why did we do this? You see, when we look at how science has progressed over the centuries, we can learn some lessons, particularly the mistakes that were made. Two major points we learned were written in bold about halfway through the module:

1. **Scientific progress depends not only on scientists, but it also depends on government and culture.**

2. **Science progresses by building on the work of previous scientists.**

I would like to add a third lesson here. We discussed throughout this module how the philosophy of the scientist often affected the work he did. This philosophy has to do with how a person views the natural world or their worldview. It is important to understand the worldview of any scientist, particularly when he takes the data he collects and then makes conclusions from it. We saw that with Darwin. He identified how organisms can change features over time from one generation to another, depending on their living conditions. (A lighter-colored bear cub might live longer than a darker one in a snow-covered environment. Then he would pass those "lighter-colored" features on to his bear cubs when he grows up.) And those observations have been identified as true. But Darwin took those ideas and went a step further to say that those changes could explain how life came to be on Earth without a Creator. There was no evidence for that. It had to do with his worldview and interpretation of the data. So we can say that

3. **The interpretation of scientific data is often dependent on the individual scientist's worldview.**

This is a point you need to understand as you go through any science course in the future. Even this course is taught from a specific worldview.

WHAT TO DO

- ❒ **Answer** study guide questions
- ❒ **Prepare for the exam**
  (review "On Your Own" questions, Student Notebook notes, and completed study guide)
- ❒ **Take exam**

Now it is time to prepare for the exam for this module. On the page following the answers to the "On Your Own" questions, you will find a study guide. This is like a practice test, highlighting all the information that I consider important material from the module. Work through it and try to answer questions (without peeking) about information discussed in the module. Then go back through the module to find the answers for the ones you don't remember. You can check your answers in the *Solutions and Tests Manual*. Once you complete it, you can use the study guide to be just that: a guide for study!

For this module and the next one, you will be instructed to take your exams as open-book exams. That means you will be able to refer to the information in your text for the exam, too. But that is to help you learn how this course works. This is a good way to get you prepared for higher-level work. Test-taking is a skill, and the best way to improve that skill is to work through the process of taking tests, figuring out the best ways you are able to study and learn the material. You are not doing this for a grade so much as you do this to learn the information in the book. And you will be equipping yourself with awesome tools to better your ability to study the world around you and give God glory! After all, the study of the world and its processes is as Johannes Kepler says: "Thinking God's thoughts after Him."

ANSWERS TO THE "ON YOUR OWN" QUESTIONS

The blue text is the answer and the black text is further explanation.

1.1 If you look at the definition of science, it contains 2 parts. Science consists of collecting facts, but it also consists of using those facts to explain the world around us. **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.**

1.2 In the experiment, the lead sinker sank down in the popcorn, and the ping-pong ball floated up. So **the popcorn kernels are more dense than the ping-pong ball and less dense than the lead sinker.**

1.3 Despite the fact that Albert Einstein is brilliant, he can be wrong, just like many other brilliant scientists. There are several examples you could use to show an example of a brilliant scientist who had incorrect ideas **(like the story of Aristotle and his incorrect belief in spontaneous generation). We should therefore not make scientific decisions based on what people believe. Instead, we should make them based on data.**

1.4 There are several reasons scientists should document their work. **Writing it down enables scientists to refer to it later. They are able to share their findings with other scientists in other parts of the world. Their data will be available for future scientists to help them further their understanding of how things work in the world.**

1.5 During this time in history, Christian scholars realized their belief that God created the universe meant He would have set up universal laws for the heavens to follow. God had unchanging laws, so the natural laws should also not change. That meant **the way the natural world worked could be explained if they could discover the natural laws God set in place.**

1.6 Galileo had access to a device that was designed for the military by Hans Lippershey. This tube with 2 lenses magnified distant objects. From that description, Galileo was able to determine how this invention worked, and he made one for himself with the intention of observing the heavens. So **Galileo took another individual's ideas and then improved on them for a different purpose. He might not have come up with his telescope idea if he hadn't had the information from Lippershey. Therefore, science progresses when scientists document their findings and make them available to each other.**

1.7 **Newton would not like such textbooks.** He believed that science had to be linked to math. There was an order to creation, and math helped to explain that order.

1.8 The fact that spontaneous generation has been demonstrated as a nonviable process causes a problem for evolutionary theory. **Evolution relies on the fact that everything in our universe arose without God. So without a Creator, evolutionists have to assume that life comes from nonlife. Yet that is spontaneous generation!**

Sample Lab Write-up for Experiment 1.1:

Experiment 1.1
Density in Nature

Sherri Seligson
1/06/2018

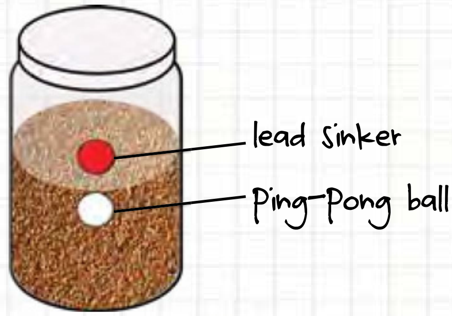
INTRODUCTION

The purpose of this lab is to explore density and how it works in nature. Some materials are denser than others. In this lab, if the 2 objects have different densities and are swirled together in the same container of popcorn, then the less-dense object will not sink as deep as the denser one.

MATERIALS AND PROCEDURE

The canister was filled with popcorn kernels and then the ping-pong ball was buried in the popcorn so that it was just below the popcorn's surface (See Figure 1). Next, the lead sinker was set on top of the popcorn. The canister was vigorously swirled around and around in a circular motion.

FIGURE 1: EXPERIMENT 1.1 SETUP



RESULTS

When the canister was swirled, the lead sinker started to sink down into the popcorn kernels. The ping-pong ball floated on top. This is because both objects are made up of atoms, and the way the atoms are packed together will determine the characteristics of each object. The lead sinker is denser than the ping-pong ball.

CONCLUSION

When the canister was swirled, the lower-density ping-pong ball floated to the top of the popcorn and the higher-density lead sinker sank into the popcorn. This demonstrates how lower-density materials will always float on top of higher-density materials.

STUDY GUIDE FOR MODULE 1

This guide will help you better understand the key information addressed in the module. It is also exactly what it is titled: a *guide* to help you *study*. Don't worry…it is not graded, but it IS a great way to see how much you remember and review more challenging information. To complete this study guide, first go through the questions and answer them as best you can. You can even make an educated guess. Then, go back through the module to find the answers to any questions you didn't remember. Once it is completed, check your answers with the answer key in the *Solutions and Tests Manual*. Now you have a great source from which to study!

1. Match the following words with their definitions.

a. Science	An ancient form of paper, made from a plant of the same name
b. Papyrus	
c. Spontaneous generation	The idea that living organisms can be spontaneously formed from nonliving substances
	The systematic study of the natural world through observation and experimentation in order to formulate general laws

2. The Egyptians were not considered scientists, even though they had incredibly advanced medical practices for their time. That is because they used the trial and error method of science. Which of these healing methods did they NOT use on patients?
   a. Egyptian doctors treated open wounds with moldy bread so the wounds would heal quickly (Penicillin created by the mold killed bacteria.)
   b. Patients were painted with mud to heal them from the common cold. (Mud kills bacteria).
   c. Patients who were experiencing pain would be given poppy seeds to eat. (Poppy seeds have morphine and codeine, which are pain-relieving drugs.)

3. What invention helped Egyptian doctors easily document information, transport it to other scholars, and store it for future generations?
   a. horse and carriage
   b. clay tablets
   c. papyrus

4. Scientists often build on one another's ideas. Anaximenes tried to explain all things in nature as being made of a single substance. Leucippus built on that idea and his student, Democritus, took that idea even further. What idea did Leucippus and Democritus propose? (Hint: Think of Democritus on the beach!)
   a. The beach is a relaxing place to do science.
   b. All matter is composed of atoms.
   c. Sand has a higher density than water.

5. True or False: Isaac Newton championed the idea of spontaneous generation and is responsible for it being believed for so long.

For questions 6–9, complete the sentence in your own words:

6. The accounts of Aristotle and Ptolemy teach us that a scientist shouldn't hold onto an idea just because ____ or just because a brilliant scientist believes it.

7. The main goal of the alchemists was to turn lead into ________________.

8. Science began to progress toward the end of the Dark Ages mainly because the ______________ worldview began to replace the Roman worldview.

9. During the Enlightenment, a major change in scientific approach took place. A good change was that science began to stop relying on the authority of _______________________. A bad change was that science began to move away from the authority of _______________________.

Short Answer:

10. Galileo built an instrument out of a tube with 2 lenses, 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? Was he the inventor of this device?

11. Charles Darwin had 2 major impacts on the progress of science when he published his ideas about the origin of species: one negative and one positive. What are they?

12. Louis Pasteur conducted experiments that dealt a final blow to the idea of spontaneous generation, the supposed production of living organisms from nonliving matter. Today, all scientists agree that spontaneous generation cannot

occur. Explain how that fact is a problem for Darwin's idea that life came to be on Earth without God creating it.

13. Yes or no: Does a scientist's beliefs affect the way he interprets data?