

GOD'S
DESIGN®

Chemistry & Ecology

Properties of
Matter

Properties of
Ecosystems

Properties of
Atoms & Molecules



MASTERBOOKS
— CURRICULUM —

Debbie & Richard Lawrence

Fourth Edition: January 2016
Master Books Edition first printing: June 2018

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Master Books®, P.O. Box 726, Green Forest, AR 72638

Master Books® is a division of the New Leaf Publishing Group, Inc.

ISBN: 978-1-68344-125-0

ISBN: 978-1-61458-649-4 (digital)

Cover by Diana Bogardus

Book design: Diane King

Editor: Gary Vaterlaus

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God's Design® for Chemistry & Ecology is a complete life science curriculum for grades 3–8. The books in this series are designed for use in the Christian school and homeschool, and provide easy-to-use lessons that will encourage children to see God's hand in everything around them.

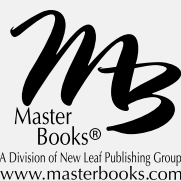
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UNIT 1

Experimental Science

- 1 Introduction to Experimental Science
- 2 The Scientific Method
- 3 Tools of Science
- 4 The Metric System

- ◇ Describe how the scientific method is used to study the world.
- ◇ Distinguish between qualitative and quantitative observations.
- ◇ Identify the proper tools and units used for measuring different properties of matter.



1

Introduction to Experimental Science

Learning about matter



How do scientists conduct experiments?

Words to know:

matter

experiment

Challenge words:

operational science

naturalism

origins science

Do you want to learn about science? I

hope so. Science can be very exciting. Why do you want to learn about science? Maybe you really like animals and want to learn more about them, or maybe you want to be an astronaut or an engineer and you know you need to learn a lot about science to do those jobs. Biology, astronomy, and physics are important parts of science. But this is a chemistry book, so why should you want to learn about chemistry?

Chemistry is the study of the material around you and how it reacts with other material. Scientists call this material matter. **Matter** is anything

that has mass and takes up space. Understanding what matter is and how it acts in different conditions is important to every other area of science. You need to understand chemistry to understand how plants and animals grow. You need to understand chemistry to understand what stars are and how they produce light. You need to understand chemistry to know how to build a computer, too. You even need to understand how one material reacts with another material to make a new recipe for dinner. So you can see that chemistry affects every area of your life.

So how do we learn about matter? One of the best ways to learn about matter is by conducting experiments. An **experiment** is a controlled test to see what happens in a certain situation. You will get to do lots of experiments in this book. Experiments will teach you what works, what doesn't work, and give you ideas of what to try next time.

Before you begin an experiment, you need to know the purpose: what are you trying to learn? You also need to know what you expect to happen. You can then design an experiment to test what you think will happen and see if you are right. Does this sound like fun? It is! So let's get started with your first experiment. ✨

What did we learn?

- What is matter?
- What do chemists study?
- What is an experiment?

Taking it further

- Why is it important to study chemistry?
- What are two things you need to know before conducting an experiment?

Chemistry is fun

Different kinds of matter act differently even under the same conditions because they have different properties. Today we are going to look at how well different types of matter conduct heat. If something is a good conductor of heat, it gets hot very quickly when it is near something hot. You might need to use pot holders to carry something that is a good conductor of heat. Something that is not a good heat conductor stays cooler for a longer period of time when it is near something hot. Most pot holders are made out of a thick cloth because cloth is not a good heat conductor. In the following experiment, you will test various substances such as wood, plastic, and metal to see which are the best conductors of heat.

Purpose: To understand how to conduct an experiment in a scientific manner

Materials: metal spoon, wooden spoon, plastic ruler, pencil, butter knife, butter, large cup, hot water, stopwatch, "Conducting Heat Experiment" worksheet

Procedure:

1. Think about what you know about different materials such as metal, glass, and wood. Which ones do you think conduct heat the best? Which ones do not conduct heat well? Place a metal spoon, a wooden spoon, a plastic ruler, a pencil, and a butter knife in order of

which ones you think would conduct heat the fastest to the slowest. Write these items on your worksheet.

2. Smear a small amount of cold butter on the end of each item.
3. Place the items, buttered end up, in a large cup.
4. Fill the cup with hot water; be sure that the butter is not in the water.
5. Use a stopwatch to time how long it takes for the butter on each object to begin to melt. Record this time on your worksheet.
6. Compare your results with your predictions.

Questions:

- Did the butter melt fastest on the item you expected to conduct the heat the best?
- Which items actually conducted heat the best? Which ones conducted heat the slowest?

Conclusion: By using your knowledge to make good predictions, following a careful plan, and checking your results, you learned about the heat conductive abilities of several materials. You will learn more about how to conduct experiments when you learn about the scientific method in the next lesson.

Operational science vs. origins science

You just learned that chemistry is the study of how different materials react with each other. This is a form of observational science. You can observe what happens when you do an experiment. Observational sciences is what you normally think of as science. A scientist can measure how far away a star is. A scientist can cross-pollinate two plants and observe what

kind of flowers or fruit they produce. Scientists test the strength of new metals or measure how much energy is in a particular sample of coal. Observational or **operational science** can be repeated and reproduced by other scientists. This is an important part of discovering how things work.

However, there is an area of science that is

not observable. This area of science tries to answer questions about the past, such as where all of the matter and energy in the universe came from. This area of science is often called **origins science** or historical science. Origins science does not deal with repeatable experiments like observational science does. Origins science looks at what we see today and tries to explain how it got here.

There are basically two views of origins. One view says there is a powerful God who created everything we see. The other view says there is no God, but only what we are able to see. This view is called **naturalism** and only accepts explanations of origins that exclude any supernatural being.

Experiments cannot be used to prove the ideas of origins. We cannot go back in time and observe the universe before there were planets. We cannot observe matter being created. In fact, all of the experiments that have been conducted in the past have shown that matter cannot be created or destroyed. This has been shown by so many experiments that it is called a scientific law. Because questions of origin cannot be tested or repeated, these areas must be accepted on faith. Either God created everything, or nature is all there is and everything developed by random, natural processes. God is the only eyewitness to creation and He has revealed in His Word that He created everything in six days (Genesis 1; Exodus 20:11).

It is important to recognize when someone is talking about operational science or origins science. When you read about scientific discoveries, you need to ask questions that will help you decide if it is observational science or origins science. Here are a few questions to help you get started in evaluating scientific claims.

1. What is this scientist claiming? What is the purpose of his investigation?
2. Is this claim based on experimentation that can be repeated, or is it trying to explain something that may have happened in the past?
3. What assumptions is the scientist making?
4. Does this claim contradict what the Bible says?

If a scientist claims to be able to show how something happened in the past, he is not dealing

with observational science, but is dealing with origins science. This is the area where creationists and evolutionists often disagree. If a scientist claims to be able to show how something works today, then she is dealing with observational science, and others can test this claim to prove whether it is true.

Below are several scientific claims. Ask yourself the previous questions and try to determine if each claim represents observational or origins science.

1. The bones of an ancient ape-like creature show the evolution of man.
2. Carbon nanotubes have great potential in electronics because of their semiconducting properties.
3. The rocks in this area are millions of years old.

The first claim is origins science. The scientist observes some bones. He sees that the bones are similar to apes that can be observed today. But the scientist has not done, nor can he do, any experiments to show how that creature evolved into another creature. The scientist is making assumptions about what the bones show without supporting experimentation. The claim contradicts the Bible's claim that God created man.

The second claim is observational science. The semiconducting properties of carbon nanotubes can be tested. Whether this potential is ever fulfilled remains to be seen, but the properties can be tested today, so this is observational science.

The age of the rocks may appear to be observational science as well. Scientists perform many tests to try and determine the age of a rock. However, these tests only give them relative amounts of elements in the rocks. The ages they assign to rocks is their interpretation of the evidence. These tests rely on assumptions that are not always true; therefore, the scientists get unreliable answers. Because this claim contradicts the Bible, it is worth investigating further. You can find more information about rock dating by going to the website for Answers in Genesis.

The theory of evolution deals with origins and is not operational science. Be a wise scientist and ask questions to help you understand the claims of other scientists.

2

The Scientific Method

How do scientists do it?



What is the scientific method?

Words to know:

scientist

hypothesis

scientific method

controlling variables

What is a scientist? A scientist is someone who uses observations and a systematic method to study the physical world and how everything in it works. **Scientists** study things that can be observed, measured, and tested.

Over the centuries, scientists have developed a way of approaching problems that is called the **scientific method**. This is not a set of rules, but a way of thinking. It is a logical, systematic approach that involves observing and testing to gain knowledge. In general, the scientific method has five steps.

1. Learn about something—make observations
2. Ask a question—identify a problem
3. Propose a solution—make a **hypothesis** (a good or educated guess)
4. Design a way to test your hypothesis—test your idea, record your observations and results
5. Check if your results support your hypothesis—draw a conclusion

Different books will list different steps or ways to perform the scientific method, but the ideas will still be the same.

You probably use this method to solve simple problems every day without even realizing it. For example, if you own a houseplant, you probably learned that plants need sunshine and water to grow. You identify a problem when you notice that your plant looks droopy. You make a hypothesis and guess that the plant needs to be watered. You test your hypothesis by watering the plant. Then you check to see if your hypothesis was right by seeing if the plant looks better after you watered it. If it does, you conclude that your hypothesis was right. This is a very simple example of how you use the scientific method frequently.

Now let's look at each step of the scientific process in a little more detail. First, you need to learn about a topic. This can be done by direct observation using your five senses. You can also do research by reading books or reports. We can and should learn from those who have gone before us. There is no sense in "reinventing the wheel" when we can find out a great deal from others' work.

Second, we can identify a problem by asking a question. This requires curiosity. Ask, "How does this work, why did this happen, or what if we tried this?" Almost all great inventions have come about



Using the scientific method

Purpose: To test which sweetener makes bread dough rise best

Materials: three identical empty bottles, masking tape, warm water, yeast, sugar, molasses, three balloons, cloth tape measure, “Scientific Method” worksheet

Procedure: Let’s apply the scientific method to a fun problem:

A. Learn: Have you ever watched bread dough rising? The dough starts out as a relatively small lump, but in a few minutes it is tall and fluffy. Bread dough rises because tiny organisms called *yeast* combine with the sweetener in the dough and give off a gas that lifts up the dough.

B. Ask a question: What is the best sweetener to use to make the fluffiest bread?

C. Make a hypothesis: Sugar and molasses are common sweeteners. Guess which one you think would work best. Write your guess on your “Scientific Method” worksheet.

D. Design and perform a test: Remember, you must control your variables.

1. Get three identical empty bottles.
2. Put a piece of masking tape on each bottle and number them 1, 2, and 3.

3. Pour 1 cup of water that is 100°F into each bottle.
4. Add 1 teaspoon of yeast to each bottle. Do not add anything else to bottle 1.
5. Add 2 tablespoons of sugar to bottle 2, and add 2 tablespoons of molasses to bottle 3.
6. Gently mix the contents of each bottle by swirling the contents for 30 seconds.
7. After mixing, place a balloon over the top of each bottle to catch any gas produced.
8. After 15 minutes, use a cloth tape measure, or string and ruler, to measure the circumference of each balloon and record your measurements on your worksheet.
9. Repeat these measurements every 15 minutes for one hour, recording your results each time.

E. Questions: Did the bottle with your chosen sweetener produce the most gas? Which sweetener would you use to make bread? Answer the questions on your worksheet.

Conclusion: Even if you guessed the sweetener that did not produce the most gas, you still learned from your experiment. Share your results with someone who did not do the experiment with you, and look for ways to apply the scientific method to other problems.

because the inventor asked, “How can we do this a better way?” God gave humans a great amount of curiosity, and He wants us to use it to improve our lives and to glorify Him.

Once we identify a problem that needs to be solved or have a question we want to answer, we need to make a guess as to what the answer will be. This answer should be based on what we have observed and learned. For example, if you have a plant that is not growing well, you may ask how you can make it grow better. You have learned that plants not only need water and sunshine, but they also need nutrients. So you guess that your plant is doing poorly because the soil does not have enough nutrients in it. This is a reasonable guess based on what you have learned. It would not be a reasonable guess to say

that the plant needs bubble gum to grow better.

The next step is to design a test that will help you decide if your guess is correct. This test or experiment should be set up to test only one thing at a time. If you change two or more things at once, you will not know which change gave the observed results. If you move the plant from a dark room into a sunny room and feed it more plant food, and then the plant starts growing better, you will not know if the added sunlight, the plant food, or a combination of both caused the change. You need to change only one thing at a time. This is called **controlling variables**. So first, keep the plant in its current location and give it fertilizer. If that helps, you know it needed nutrients. If the plant does not improve, try moving it to a sunny location. Changing only one thing at a

Scientists follow careful procedures when conducting experiments.



time will help you determine why you got the results you did.

Finally, after you complete your test, you need to check and see if the results show that your hypothesis is correct or not. It is okay to have a wrong hypothesis! When Thomas Edison was trying to find a material that would work for the light bulb, he tried hundreds of different materials before he found one that worked. The important thing is to try to understand why your hypothesis was wrong, and to try to come up with a better idea next time. This is how scientists learn. Also, it is important to share your results so that others do not make the same mistakes you did, and so they can learn from your successes as well.

There are limitations to the scientific method. We cannot answer all questions nor can we solve all problems by experimentation. The scientific

method can only be used on physical materials. So we cannot use science to establish truth, to make moral judgments, or to determine what is right and wrong. We must use God's Word to help us decide these kinds of issues.

Also, the conclusions drawn from experiments can be affected by the scientist's beliefs. For example, many scientists do not believe there is any power outside of the physical world. Therefore, they interpret the results of their tests in light of that idea. When they look at the world today, they think that it got the way it is by natural forces only. However, when a scientist who believes the Bible sees the world, he understands that God created the universe, and that our world has been affected by the curse God put on the earth when Adam disobeyed, and by the Genesis Flood when God judged man's wickedness. Our beliefs affect how we interpret our test results. As Christians, we need to take God's Word first, and then interpret our world in light of what He says, because we know that God cannot lie. ✨

What did we learn?

- What is the overall job of a scientist?
- What are some areas that cannot be studied by science?
- What are the five steps of the scientific method?

Taking it further

- Why was it necessary to have bottle number 1 in the experiment?
- What other sweeteners could you try in your experiment?
- What sweeteners were used in the bread at your house?
- Why do you think that sweetener was used?



Design your own experiment

Show that you understand the scientific method by designing your own experiment. You can test any hypothesis that your parent or teacher approves of. Follow the steps you have learned in the lesson. Make your own data sheet, record your data, show how you are controlling your variables, and be sure to write up a conclusion to share with others. If you need ideas for where to start here are some suggestions of things you can test:

- Which brand of battery lasts the longest?
- Which paper towel is the strongest?
- Does music affect plant growth?
- Are childproof caps really childproof?
- Which laundry detergent gets out stains the best?

3

Tools of Science

Using the right tool for the job



What's the difference between qualitative and quantitative observations?

Words to know:

qualitative observations

quantitative observations

Challenge words:

microscope

eyepiece

objective lens

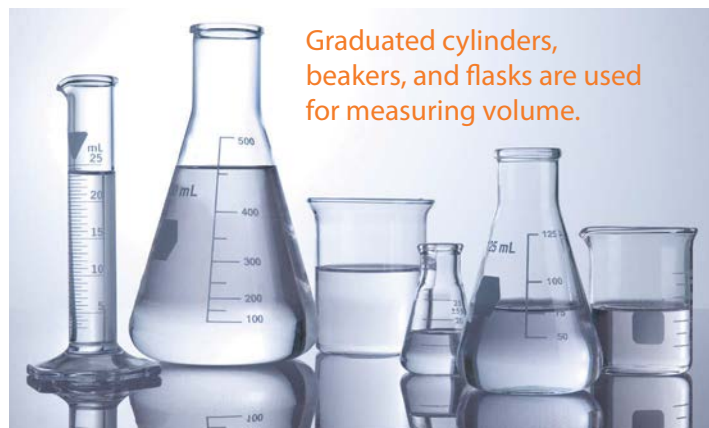
reflecting telescope

Every person who performs a job requires special tools. A cook needs measuring cups, a mixer, an oven, and pots and pans. A carpenter needs hammers, saws, sanders, and many other tools. An athlete needs weight equipment, running shoes, special clothes, ice skates, etc. So also, a scientist needs special tools to do his or her job.

A scientist's main job is to make observations. There are two kinds of observations that a scientist makes: qualitative observations and quantitative observations. **Qualitative observations** are ones that do not involve numbers. For example, a scientist may observe the color or texture of a material before, during, and after an experiment. The main tools that a scientist uses for qualitative

observations are his five senses. What qualities might you observe with your five senses? You might see color, bubbles, smoke, size, etc. You could smell odors, hear popping, or taste flavors. And you could feel the texture and temperature of the object. Please note that you should **never** taste any unknown substance!

Qualitative observations are very useful; however, they are dependent on the observer. What one person considers red, another may describe as purple or pink. One person may describe a light as very bright, while another does not. Therefore, qualitative observations are limited in their usefulness. Whenever possible, scientists choose to make quantitative observations. **Quantitative observations** involve numerical data.



Graduated cylinders, beakers, and flasks are used for measuring volume.



Modern electronic balances have replaced traditional beam balances.

Scientists have a number of tools to help them make quantitative observations. These include a balance for measuring mass, graduated cylinders for measuring liquid volumes, thermometers for measuring temperature, and spectrometers for measuring the wavelength of light. The list goes on and on. These tools provide unbiased data with which

scientists can determine the exact results of an experiment. Quantitative measurements allow scientists to compare their results with others' results.

Scientists often generate so many numbers in their experiments that it may be difficult to analyze them all, so one of the most important tools a scientist uses is the computer. Computers are ideal for compiling and analyzing large groups of numbers.

Although quantitative data are preferred, they have limitations as well. Measurement tools have limits on their accuracy. For example, an analog wristwatch with a second hand cannot measure any time period more accurately than to the nearest second. A more accurate digital timer would be needed to measure a reaction that happens in microseconds. A scientist must know the limits of her tools and use the best tool for the job. As a scientist, you must learn to make good quantitative observations and good qualitative observations as well. ✨

What did we learn?

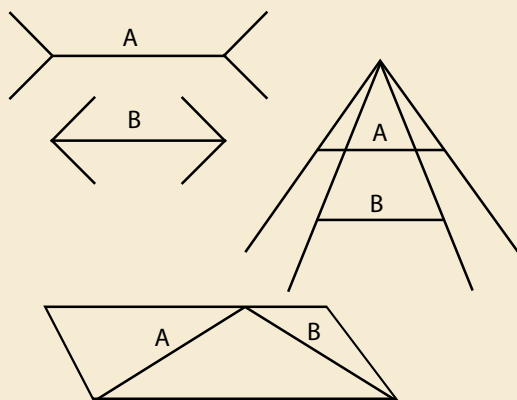
- What is the main thing a scientist does as she studies the physical world?
- What are the two types of observations that a scientist can make?
- What is the main problem with qualitative observations?
- What are some scientific tools used for quantitative observations?

Taking it further

- What qualitative observations might you make when observing the experiment in lesson 1?
- What quantitative observations might you make when observing the experiment in lesson 1?

Fun Fact

Qualitative observations can sometimes be unreliable. Our eyes are easily deceived. In each picture below, tell whether you think line A or line B is longer.



It appears that line A is longer in each picture; however, lines A and B are actually the same length in each picture. Measure each line with a ruler to convince yourself. Quantitative observations can help prevent mistakes that we might otherwise make.

Learning to use your tools

Complete each task on the "Scientific Tools" worksheet.



Magnifying objects

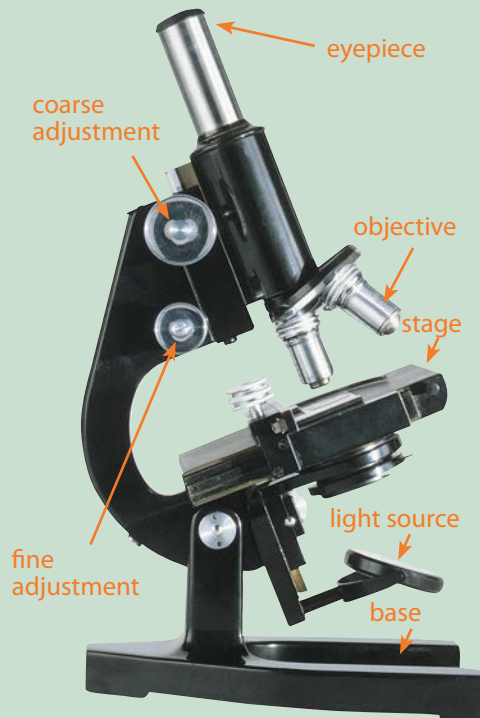
Two of the most important scientific instruments are the microscope and its cousin the telescope. Both of these instruments use lenses to magnify an image. **Microscopes** are used to make very small objects appear larger so you can see more detail. A microscope uses two types of lenses.

The first lens is called the **objective lens**. The objective is close to the object that is being viewed. At the top of the microscope is another lens called the **eyepiece**. Some microscopes have two eyepieces so you can use both eyes to look at the object. The objective magnifies the image a certain amount. It could be 10 times or 100 times. Then the eyepiece magnifies that larger image another 10 times. So what you see may appear to be 100 or even 1,000 times bigger than it actually is.

To properly use a microscope, place a slide containing what you wish to view on the stage. Watch the objective as you lower it all the way down until it is nearly touching the slide. Do not look through the eyepiece while lowering the objective or you may lower the lens into the slide causing damage to the slide and/or the lens. After you have lowered the objective, you can look through the eyepiece as you slowly raise the objective until the object comes into focus.

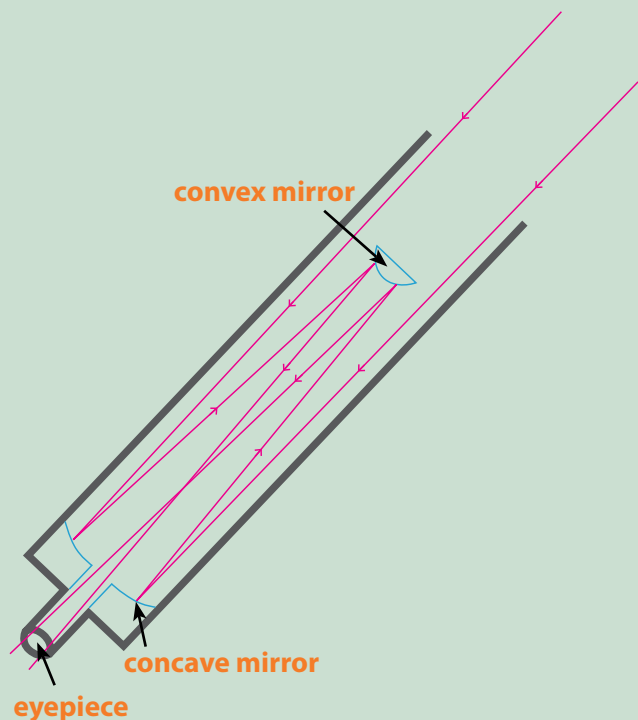
Most microscopes have a coarse and a fine adjustment for moving the objective. Use the coarse adjustment until the object is nearly in focus, then use the fine adjustment to bring the object into sharp focus. Some microscopes have knobs that can be used to move the stage to allow you to view different areas of the slide while looking through the eyepiece. Many microscopes have clips to hold the slide in place. If you have access to a microscope and slides, use what you have learned here to safely view the objects on your slides. If you do not have any prepared slides, you can view some salt and sugar crystals to see the differences in their shapes.

A telescope also uses lenses to enlarge an image, but telescopes are used to view objects that are very far away rather than to view objects that are very small. A **reflecting telescope** (pictured at right) actually uses a series of lenses and mirrors to enlarge the image without distortion. Light from a distant object enters the front of the telescope and reflects off the concave mirror near the back of the telescope. The reflected light then reflects off of a convex mirror



near the eyepiece where it passes through a lens.

If you have a telescope available, you can use it during the day to view objects that are far away such as a building or a tree. At night you can use it to view the moon and the stars.



Lord Kelvin

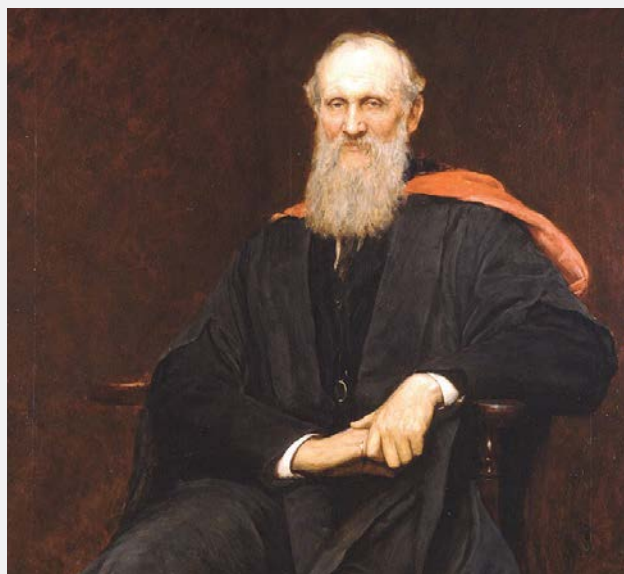
1824–1907

William Thomson, or Lord Kelvin, was the fourth child of seven, born on June 26, 1824, in Belfast, Ireland. His mother died when he was six years old. His father wrote textbooks and taught math at a university in Belfast and he took on the task of teaching the newest math to William. William had a very close relationship with his father. Over the next several years he learned much about math and wrote several papers. By the time he was 15 he had won a gold medal for his exceptional mathematical ability.

When William Thomson was 16 he entered Cambridge, and four years later earned a bachelor's degree with high honors. At 22 years of age William was unanimously elected the Chair of Natural Philosophy (physics) at the University of Glasgow, where he stayed until he was 75 years old. Much of William's work involved a theory that electricity and magnetism are related, and that electromagnetism and light are related. His work enabled James Clerk Maxwell to formulate his famous equations describing electromagnetism, which is considered by some to be the most significant achievement of the nineteenth century. (See the Special Feature on Maxwell on page 45.)

Thomson was also very involved in the work behind laying the first transatlantic telegraph cable. After much work and controversy, his design was selected and was successful. Because of the patents he held on some of the equipment used to transmit and receive the signal, he was knighted in 1866 by Queen Victoria and thus became Lord William Thomson of Kelvin, or Lord Kelvin.

Because of the success of the transatlantic cable, Lord Kelvin became a partner in two engineering consulting firms. These firms played a major role in the construction of submarine cables. This made him a wealthy man. With some of that wealth he bought a huge yacht and a magnificent estate.



Lord Kelvin's interest in science was very broad; he did research in electricity, magnetism, thermodynamics, hydrodynamics, geophysics, tides, the shape of the earth, atmospheric electricity, thermal studies of the ground, the earth's rotation, and geomagnetism.

In 1884 Lord Kelvin developed an analog computer for measuring and determining the tides in a harbor for any hour, past or future. And he started a company to manufacture these devices. He also went on to publish a textbook on natural philosophy or physics, as it would be called today. He received honorary degrees from all over the world. He was said to be entitled to more letters after his name than any other man in the United Kingdom.

Out of all his scientific discoveries, Lord Kelvin is most remembered for his work in accurately measuring temperatures. He developed the temperature scale used by almost all scientists around the world. It is named after him, and is called the Kelvin scale. The Kelvin scale starts at absolute zero, the temperature at which all movement of molecules

ceases. This means that zero degrees kelvin is the coldest anything can get; it's the lowest temperature possible.

In spite of all his great discoveries, Lord Kelvin still made mistakes. In 1900, at an assembly of physicists, he stated, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement." He also stated that heavier-than-air flying machines were impossible. This just goes to show that even a highly respected physicist can make mistakes in his field, even though most of his work has been shown to be correct.

Lord Kelvin was also a very insightful man. In his time, many new theories were being developed. Some had merit and others did not. In 1847 he heard about Joule's theory on heat and the motion of heat, which went against the accepted knowledge of the day. Kelvin studied this new theory and later gave his cautious endorsement of it. He also worked to advance the theories of Faraday and Fourier, as well as Joule.

However, when Charles Darwin's theory of evolution was first published, Lord Kelvin opposed it. He believed that all science must be subjected to the same rigors, and he applied what he knew about science to the theory of evolution. Darwin's theory was based on the assumption that life had evolved over a very long time (at that time Darwin believed the earth was millions of years old) during which the forces of nature remained fairly constant, and that nature operated millions of years ago just as it does

today. Lord Kelvin based his opposition to evolution on the theory of thermodynamics, showing that the earth would have been considerably hotter only one million years ago and any life that lived at that time would have been very different from what can live today. He also showed that these conditions would have produced violent storms and floods over the earth. Also, the second law of thermodynamics, which was developed by four of Kelvin's contemporaries, shows that in a closed system the natural order of things is to become more disorganized, which clearly contradicts Darwin's theory that living things, over time, become more organized and more complex.

William Thomson (Lord Kelvin) lived an exemplary Christian life. He spent much of his time showing that science supports the idea of an intelligent creator. He wrote, "Mathematics and dynamics fail us when we contemplate the earth, fitted for life but lifeless, and try to imagine the commencement of life upon it. This certainly did not take place by any action of chemistry, or electricity, or crystalline grouping of molecules under the influence of force, or by any possible kind of fortuitous concourse of atoms. We must pause, face to face with the mystery and miracle of the Creation of living creatures." Lord Kelvin believed the Bible when it says that God spoke all life into existence.

Lord Kelvin died on December 17, 1907, at the age of 83. He is buried in Westminster Abbey in London, and a stained glass window has been installed in his honor.

4

The Metric System

Standard units

What units do scientists use to measure things?

Words to know:

meter gram
liter

Challenge words:

Mohs scale Fujita scale
Beaufort scale Saffir-Simpson scale

Scientists from around the world often work together on projects. In order to do this, they must overcome language barriers and other obstacles. One way scientists overcome the language problem is by using Latin terms whenever possible so there is less confusion. They also use numbers to reduce confusion. Because numbers and quantitative data are so important to science, a standard system for measuring has also been adopted by the scientific community.

The traditional system of measuring used in America is based on the Old English measures established during the Middle Ages. These measurements include the inch, foot, yard, mile, rod, hand, and span

for length; the ounce, pound, and ton for weight/mass; and the fluid ounce, cup, pint, quart, and gallon for liquid volume. Because the conversion between units is difficult to use and remember in the Old English/American system, the scientific community has adopted the metric system. The metric system is often referred to as SI units, from the French term *Système International* (International System).

The metric system is very easy to use and to remember. All conversions from one unit to another are multiples of 10, so the math is easy. Each type of measurement is based on a standard unit. These units include the **meter** for length (hence the name metric system), the **liter** for liquid volume, and the **gram** for mass. The metric unit for time is the second; for temperature it is degrees kelvin; and for electrical current it is the ampere. If you wish to measure something that is significantly smaller than the standard unit, you use a unit that

Fun Fact

A meter was originally defined as 1/1,000,000 of the distance from the North Pole to the equator. But it has been redefined to be 1,650,763.73 times the wavelength of light given off by the element krypton-86.

is the standard unit divided by 10 or 100 or some other multiple of 10. For example, to measure the length of a paper clip you would use a unit that is a meter divided by 100—a centimeter. To measure something that is significantly larger than the standard you would use a unit that is that standard unit times some multiple of 10. For example, to measure the mass of a paper clip you can use a gram. But to measure the mass of a person you would want to use a unit that is 1,000 times bigger than a gram, called a kilogram.

Prefixes & conversions for metric units

	X1,000,000
	mega (M)
	X1000
	kilo (k)
	X 100
	hecto (h)
	X 10
	deka (da)
	Basic Unit
	meter (m)
	gram (g)
	liter (l)
	1/10
	deci (d)
	1/100
	centi (c)
	1/1000
	milli (m)
1/1,000,000	
micro (μ)	

This chart demonstrates how the metric system works. The appropriate prefix is applied to the name of the basic unit. For example, the prefix for 1,000 times is kilo, so 1,000 meters is a kilometer and 1,000 grams is a kilogram. The symbol in parentheses shows the abbreviation used for that unit. For example, a centimeter is abbreviated cm and a kilometer is shown as km. At first, using metric units may seem strange because they are different from what you are used to, but after you use them for a while, you will find that they are much easier to use than the Old English/American units. Besides, it will help you to understand what other scientists are talking about. ✨

Fun Fact

The origin of the Old English units is very interesting. In the Middle Ages, an inch was equal to the length of three barley seeds placed end to end. And a yard was equal to the distance from the tip of the king's nose to the end of his outstretched hand. As you can imagine, these lengths varied from time to time so they were never quite accurate. However, the units we use in America today no longer vary with the size of a barley seed or the size of a king. Instead, we have standard measurements. The information necessary for verifying these standard measurements is provided by the National Institute of Standards and Technology (NIST) in Boulder, Colorado. NIST develops and supplies references that companies and other organizations use to check the accuracy of their equipment.

What did we learn?

- What are some units used to measure length in the Old English/American measuring system?
- What is the unit used to measure length in the metric system?
- What metric unit is used for measuring mass?
- What metric unit is used for measuring liquid volume?
- Why do scientists use the metric system instead of another measuring system?

Taking it further

- What metric unit would be best to use to measure the distance across a room?
- What metric unit would you use to measure the distance from one town to another?
- What metric unit would you use to measure the width of a hair?

Using metric units

Purpose: To become more familiar with the terminology of the metric system

Materials: 1-liter container, metric measuring cup, meter stick, paper clip, pencil

Activity 1—Procedure:

1. Take a giant step—that is about equal to a meter.
2. Now start at one side of the room and measure how many giant steps it takes to cross the room. That is close to how many meters it is from one wall to another.
3. Use a meter stick to get a more accurate measurement after you have walked the distance.

Activity 2—Procedure:

1. Use your hands to show how big a soft drink bottle is. Most bottles of soft drink are 2 liters.
2. Now show how big half a bottle of soft drink would be. This is about 1 liter.
3. Find a container that holds approximately 1 liter of liquid. Verify the container's volume with a measuring cup marked in milliliters or liters.

Activity 3—Procedure:

1. Hold a paper clip in your hand. A small paper clip is about $\frac{1}{2}$ gram.

2. Now hold a pencil. How does a pencil compare to a paper clip? (It is heavier.) How many grams do you think a pencil is? (It depends on the size of the pencil, but could be about 5–10 grams.)
3. If you have a gram scale, measure the mass of the pencil to see how close your guess is.

Activity 4—Procedure:

1. For older children with sufficient math skills: use the conversion chart to answer the following questions. Each step on the chart represents a multiple of 10.
 - If you pour 1,000 ml of water into a bottle, how many liters of water do you have?
 - If you weigh 20 kg, how many grams do you weigh?
 - If it is 40 hectometers from your house to your best friend's house, how many meters must you walk to get from your house to his?
 - If your pet hamster is 60 mm long, how long is she in cm?
 - If you have 5 dekagrams of chocolate to share, how many decigrams do you have?



Measuring scales

Although using the metric system is ideal for many applications in science, not everything can be easily measured and described using meters, liters, or grams. For example, how do you measure the hardness of a rock or mineral? There are SI units for area, volume, length, density, force, and voltage, but there are no units for hardness. So scientists have developed a special scale to describe relative hardness of a rock or mineral. This scale is called the Mohs hardness scale. The **Mohs scale** assigns a number from 1 to 10 with 1 being the softest and 10 being the hardest. Talc is the softest mineral and diamond is the hardest. Other rocks and minerals have been assigned numbers based on how their hardness compares to these and other minerals.

Storms are also difficult to measure with the metric system. It is possible to measure wind speed in kilometers per hour and the amount of rainfall in centimeters, but those measurements do not fully describe a storm. It is helpful to have some idea of what effects a storm will have if it passes through an area, so scientists have developed several different scales to describe storms. The

Beaufort scale describes wind, assigning numbers from 0 to 12 where 0 is calm—no wind—and 12 is hurricane force winds. Each number has a wind speed range associated with it as well as visible effects. For example, if the wind is a level 4 the wind would be described as a moderate breeze, the wind speed would be 21–29 km/h and the effects would be dust raised and small branches moving.

The **Fujita scale** measures tornado intensity on a scale of 0 to 5. An F0 tornado is called a gale tornado and does some damage such as breaking down chimneys, breaking tree branches, and damaging billboards. The Fujita scale describes the damage done by the storm rather than the size or shape of the funnel. There is a similar scale for describing hurricanes called the **Saffir-Simpson scale**, which rates the intensity of the hurricane from 1 to 5.

Earthquakes are another natural phenomenon that is not easily measured. Do some research and see if you can find out two different ways that earthquakes are measured.