Buckle Down™

2ND EDITION

7–8

Science

Buckle Down Publishing

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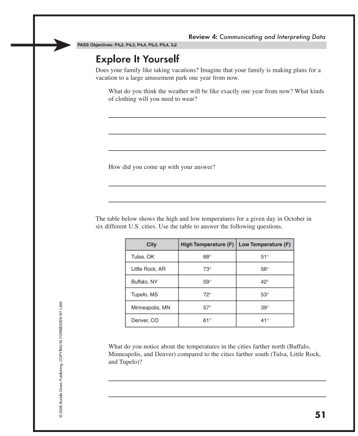
To the Teacher:

"Science Standard and Concept" codes are listed for each review in the table of contents and for each page in the shaded gray bars that run across the tops of the pages in the workbook (see example to the right). These codes indicate which *Buckle Down* science standards and concepts are covered in a given review or on a given page.



Review 4: *Communicating and Interpreting Data*

PASS Objectives: P4.2, P4.3, P4.4, P5.3, P5.4, 3.2

Explore It Yourself

Does your family like taking vacations? Imagine that your family is making plans for a vacation to a large amusement park one year from now.

What do you think the weather will be like exactly one year from now? What kinds of clothing will you need to wear?

How did you come up with your answer?

The table below shows the high and low temperatures for a given day in October in six different U.S. cities. Use the table to answer the following questions.

City	High Temperature (F)	Low Temperature (F)
Tulsa, OK	68°	51°
Little Rock, AR	73°	56°
Buffalo, NY	59°	42°
Tupelo, MS	72°	53°
Minneapolis, MN	57°	39°
Denver, CO	61°	41°

What do you notice about the temperatures in the cities farther north (Buffalo, Minneapolis, and Denver) compared to the cities farther south (Tulsa, Little Rock, and Tupelo)?

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Review 1

The Formation of Scientific Knowledge

Think about all the kinds of scientific research you've heard about: Geneticists probing the secrets of DNA, marine biologists tracking whales across oceans, and cosmologists considering the beginning of the universe. These pursuits have a common goal—to discover and explain the patterns at work in natural systems. Scientists develop theories that explain their observations and predict events not yet witnessed. As scientists gather more evidence, however, scientific theories can change. This review focuses on how scientific theories form and why they sometimes change.

What Is a Scientific Theory?

If you look in a dictionary, you'll see that most words have a few meanings. Take the word theory. It has both an everyday meaning and a scientific one.

Give an example of how you might use the word theory in its everyday sense.

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Find and write down the scientific meaning of the word theory.

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How does the scientific meaning of theory differ from its everyday sense?

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Words to Know

- alpha particle
- atom
- atomic nucleus
- bias
- description
- electron
- element
- explanation
- hypothesis
- inference
- observation
- plum-pudding model
- theory

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Science Standards and Concepts: NS.A.2, NS.A.3, PS.A.5–6

When you use the word theory in everyday speech, you usually mean "hunch" or "good guess." Scientific theories are a much stronger claim of knowledge. In science, a **theory** is a dominant explanation that is supported by a mountain of evidence. A theory explains how many different events and facts are related to each other, and it makes predictions about events and facts not yet seen. The theory of gravity, for example, explains how the force that pulls apples to the ground also keeps the Moon orbiting the Earth. Nineteenth-century astronomers used the theory of gravity to predict the existence of the planet Neptune long before they actually saw it. Obviously, the theory of gravity is more than a hunch: It describes and predicts the effects of gravity on small and large scales.

But scientific theories can change. If scientists find data that contradict the theory, then they might alter the theory. If scientists find a lot of data that the theory cannot explain, then they may propose a **hypothesis** that explains the new data and makes new predictions. Other scientists will run experiments and collect data to test the hypothesis. If the hypothesis stands up to repeated testing, explains a wide range of data, and makes successful predictions, then it may become a theory.

For over 2,000 years, most scientists believed that everything in the universe orbited the Earth. Suggest one reason why this theory, now disproved, was so successful.

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Early Atomic Theory

Today, we take for granted that matter is made of **atoms**—bits of matter too tiny to see. But 120 years ago, scientists did not agree on what atoms were, and some doubted whether they even existed. The development of the theory of the atom shows how scientific theories change in response to new findings. It also shows how a new theory can interpret old findings in new ways.

Our story begins with Democritus, a Greek philosopher who lived nearly 2,500 years ago. Democritus asked a simple question: What would happen if you took a piece of matter, like a stone, and kept cutting it into smaller pieces? Eventually, you would get to a piece of matter so small that you could no longer divide it. Democritus called this smallest piece of matter an atom, which comes from a Greek word meaning "uncuttable."

For a long time, most scientists did not accept the idea that atoms might be real. During the early nineteenth century, however, the idea of atoms got a boost. At this time, scientists developed the modern idea of an **element**, which is a substance that cannot be broken down into simpler substances. Water, for example, is not an element because it can be

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broken down into hydrogen and oxygen. Scientists of the day could not break down hydrogen and oxygen into simpler substances, so scientists called them elements. These scientists reasoned that it was impossible to break down the smallest unit of an element into any simpler substances. In other words, the smallest unit of an element was "uncuttable." So, following Democritus's lead, the nineteenth-century scientists called the smallest unit of an element an atom.

The smallest unit of carbon dioxide (CO_2) can be split apart into one atom of carbon and two atoms of oxygen. Is CO_2 an element? Explain.

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Throughout the nineteenth century, evidence mounted that atoms really existed. By the end of the nineteenth century, many (but not all) scientists believed that atoms were real. The scientists who accepted that atoms were real had a few assumptions about them.

- First, the scientists assumed that atoms were solid and indestructible, like tiny, hard balls.
- Second, the scientists assumed that each element was made of a different kind of atom. So, an atom of carbon was different from an atom of gold, and so on. The scientists did not know whether atoms had anything in common other than their small size.
- Third, the scientists assumed that atoms contained no electrical charges. That is, they assumed that atoms held neither negative nor positive charges but were simply neutral (held no charges). Experiments seemed to confirm this assumption. For example, an electric field will change the motion of particles with positive and negative charges, but it will *not* affect the motion of neutral particles. When scientists exposed gases (which are made of atoms) to electric fields, the motion of the atoms in the gases did not change. This seemed to confirm that atoms contained no charged particles.

State two assumptions that scientists in the late nineteenth century made about atoms.

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Science Standards and Concepts: NS.A.2, NS.A.3, PS.A.5–6

Discovery of the Electron

By the end of the nineteenth century, scientists began making discoveries that their atomic theory could not explain. In 1897, an English scientist named J. J. Thomson discovered a new particle of matter. An electric field affected the motion of this particle, which turned out to have a negative charge. The real shock, however, was the mass of this particle. Experiments showed that it was about $\frac{1}{2000}$ the mass of a hydrogen atom! Compared to this new particle, an atom was enormous. Thomson also realized something else. This wasn't just any particle—it was the carrier of electricity. For this reason, Thomson named the particle the **electron**. (When electricity flows through a wire, for example, electrons are moving from one place to another.) Later experiments showed that electrons moving at great speeds could pass through thin layers of solid matter.

The discovery of the electron led scientists to ask new questions about atoms and matter. Scientists had known for nearly 100 years that mixing together certain chemicals can make electricity. (This is how batteries work.) Now these scientists realized that mixing these chemicals was somehow producing electrons. But where did the electrons come from? Scientists agreed that electrons could not appear out of nowhere; they had to be a part of atoms. After 2,000 years, an important part of the old atomic theory had been disproved. The atom was not "uncuttable" after all. Somehow, you could chip electrons off them.

But the discovery of the electron raised new questions for the scientists. If the negatively charged electrons were parts of atoms, then why did other experiments show that atoms were neutral? And, how could electrons pass through solid matter? Why didn't the matter stop the electrons from moving?

You are a nineteenth-century scientist. The latest information suggests that atoms contain electrons. Propose a model of the atom explaining how an atom can hold a number of negative particles and also be electrically neutral.

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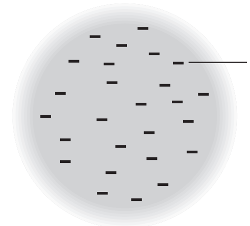
Cross-Section of "Plum-Pudding" Atom



Thomson kept experimenting. In 1904, he offered a new model of the atom. The atom, he said, was not a solid ball made of the same stuff through and through. Instead, it was a combination of two things: tiny, negative particles (electrons) and a larger, cloudlike, positive sphere. The atom's mass and its positive charge were not focused anywhere in the sphere. Instead, they were spread throughout. The electrons were stuck in this sphere, and the individual negative charges and the positive cloud canceled each other out. This model explained how atoms could hold negatively charged particles but still be electrically neutral. It also explained how high-speed particles, such as electrons, could pass through thin layers of solid substances; they zipped through the cloud. Thomson's model came to be called the **plum-pudding model**, after a popular English cake that had raisins all through it.

More findings followed Thomson's 1897 discovery of the electron. In 1898, the scientist Ernest Rutherford discovered that the element uranium emits two types of particles: electrons, and something that came to be called **alpha particles**. Like electrons, alpha particles can travel through thin sheets of solid matter. But alpha particles differ from electrons in two ways. First, alpha particles are far more massive than electrons—over 7,000 times as massive. Second, alpha particles have a *positive* electrical charge.

Remember: "opposites attract, likes repel." Predict what will happen if an electron is brought near an alpha particle.

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Predict what will happen if two alpha particles are brought near each other.

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Rutherford soon discovered that an alpha particle is actually a helium atom that has lost its electrons. This is why an alpha particle has a positive charge: With the electrons gone, nothing cancels the positive charge that remains. Rutherford also learned that alpha particles can move at incredible speeds—an average of 16,000 kilometers per second! Despite these great speeds, however, alpha particles did not always travel in straight lines. When they "bumped" into particles of gases, liquids, and solids, the direction of their motion changed slightly.

You are a mad scientist with a peashooter that can fire a pea at 16,000 kilometers per second. You fire a pea at a thin wall made of plum pudding. Predict what will happen.

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Science Standards and Concepts: NS.A.2, NS.A.3, PS.A.5–6

The Birth of Modern Atomic Theory

Rutherford and his assistants experimented on alpha particles for many years. In spring 1909, they performed an experiment that has become very famous: They aimed a beam of alpha particles at an extremely thin piece of gold foil. Rutherford—who at this time accepted the plum-pudding model of the atom—predicted that two things would happen. First, he predicted that all of the alpha particles would go through the thin gold foil. Second, he predicted that the paths of most of the alpha particles would bend slightly as they interacted with the positively charged clouds of the gold atoms.

But here's what happened instead:

- First, most of the alpha particles went through the gold foil. This made sense: An alpha particle, traveling at incredible speeds, could zip through the clouds of the gold atoms.
- Second, the paths of only a *few* of the alpha particles were bent by their passage through the gold foil. This made less sense to Rutherford. According to the plum-pudding model, most (and maybe all) of the paths of the alpha particles should have been slightly bent because of their interactions with the positively charged clouds of the gold atoms. Instead, most of the alpha particles zipped through the gold foil as if the atoms that made up the gold foil were mostly just empty space.
- The third thing that happened made no sense at all. A few of the alpha particles—about 1 in 8,000—bounced off the foil and came right back! Rutherford was amazed. How could anything that moved so fast bounce off a cloud? Years later, Rutherford described his astonishment in this way: "It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch [cannon] shell at a piece of tissue paper and it came back and hit you."

Experiments sometimes seem like recipes: gather the ingredients, mix them up, and get the predicted results. Explain how Rutherford's gold-foil experiment contradicts this "recipe" model of scientific experimentation.

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Rutherford tested and retested his results, just to be sure they were accurate. They were. So, to explain his results, Rutherford had to come up with a new model of the atom. After two years of work and thought, he published a new model of the atom's structure. Like any new model, it had to do two things: It had to look at the old findings in a new way, and it had to explain the new findings.

Name one old finding that Rutherford's model of the atom had to explain.

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Name one new finding that Rutherford's model had to explain.

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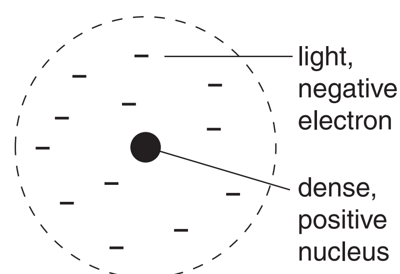
Rutherford's Nuclear Atom



Rutherford explained that an atom is *not* a positive cloud filled with negative particles. Instead, an atom is more like a tiny solar system. At the atom's core is a tiny, massive, and positive **atomic nucleus**. The nucleus contains 99.9% of the atom's mass and all of its positive charge. Around the nucleus whirl the electrons. Between the electrons and the nucleus is nothing—utterly empty space. How small is the nucleus? If an atom grew to the size of a baseball field, the nucleus would be a pea on the pitcher's mound. How dense is the nucleus? A helium nucleus the size of a pea would weigh 250 million tons; a gold nucleus would weigh 12 billion tons. How much empty space is between the nucleus and the electrons? If the pea-sized nucleus is on the pitcher's mound, then the nearest electron is a dust speck in the bleachers.

The diagram on the following page shows how Rutherford's model explained the results of his experiment where the plum-pudding model could not.

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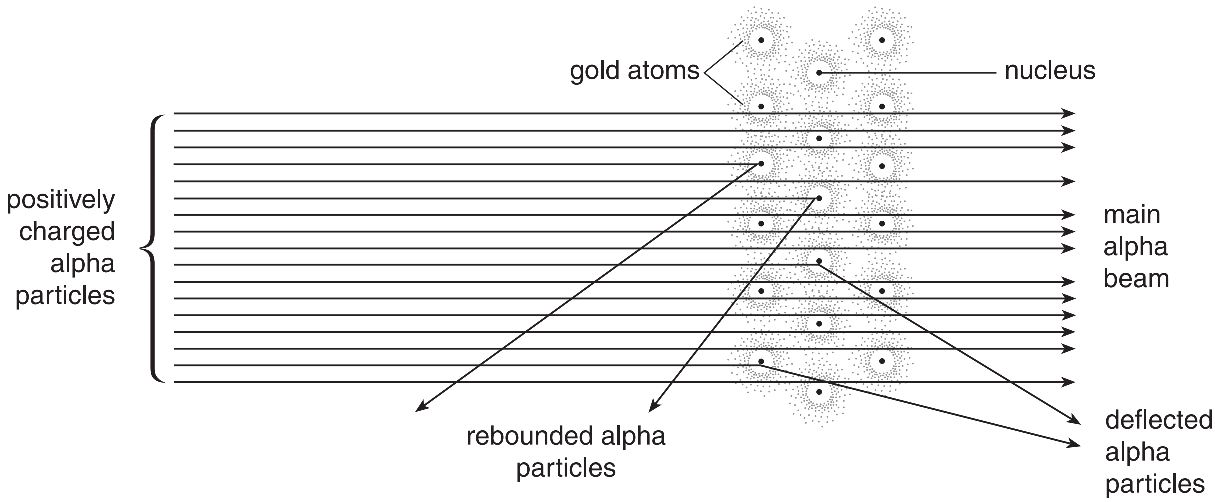
Science Standards and Concepts: NS.A.2, NS.A.3, PS.A.5–6

Atom-Level View of Rutherford's Gold Foil Experiment



An alpha particle is a helium nucleus—tiny, dense, positive, and fast. Most of these particles can zip through the gold foil because gold atoms, like all atoms, are mostly empty space. If an alpha particle comes near a gold nucleus, the two nuclei push on each other, and the alpha particle's path changes slightly. But if an alpha particle hits the massive, dense, positive gold nucleus head-on, then the particle bounces back. Only something massive and positively charged could make a fast-moving alpha particle bounce back.

Rutherford's model explained the old findings—the atom's neutrality and the existence of electrons—in a new way. It also successfully explained the new findings—the fast-moving alpha particles bouncing off a thin foil. The new model of the atom still had some gaps. Exactly how did electrons move around the nucleus? Why did the negative electrons not smash into the positive nucleus, like meteors hitting a planet? Other scientists soon solved these problems. But Rutherford's basic model—a dense, positive nucleus surrounded by light, negative electrons—is the basis of modern atomic theory.

The story of how scientists discovered the structure of the atom is a good example of how scientific knowledge forms. Scientists use theories to make sense of a set of facts. If new evidence suggests that the theory needs changing, then scientists suggest hypotheses that explain the old findings and make sense of the new ones. Scientists then test these hypotheses and adjust them as necessary. If a hypothesis is strong enough and makes sense of many findings, then it becomes a theory. But any scientific theory—no matter how strong, no matter how many findings it explains—is open to questioning and testing. That is one of the great strengths of scientific knowledge: It is always open to improving itself.

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How Science Reduces Bias

Bias is a point of view that affects the way that people interpret events. Put another way, bias is a person's tendency to see the world as he or she wishes it to be (or fears it to be), not as the world actually is. Bias is not, in itself, a bad thing. Every human being sees the world in a certain way. One goal of scientific thinking, however, is to find out how the world *actually* works, not just how humans *believe* it works.

Suppose that Dr. Slyde develops a new substance, which he calls slyderite. He claims that his experiments have shown that slyderite, if applied in a thin coat, can make a surface nearly frictionless. If Dr. Slyde's claim is true, slyderite could be incredibly useful. In cars, pistons have to be lubricated with oil. If these parts were coated with slyderite, people would use much less oil. And consider large ships. A large ship traveling across the ocean uses a lot of energy overcoming the friction of the water against its hull. A hull coated with slyderite could decrease the amount of fuel needed for the ship to cross the ocean. The possibilities are endless.

Why might Dr. Slyde have a bias in making his claims about slyderite?

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What could the scientific community do to see whether Dr. Slyde has such a bias?

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One important way that the scientific community reduces bias is to repeat an experiment and reproduce its results. The words repeatable and reproducible are similar, so we should look at their scientific meanings. An experiment is repeatable if more than one scientist or team of scientists can do it. When a scientist reports an experiment, he or she includes more than the hypothesis, the data, and the conclusion. The scientist also describes

- the materials used in the experiment,
- the steps followed in that experiment, and
- anything else that may have influenced the results of the experiment.

With such information, other scientists can try the experiment themselves to see if they get similar results.

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Science Standards and Concepts: NS.A.4, NS.A.5

The results of an experiment are reproducible if the scientists duplicating the experiment get similar results. If the scientists get results that are not close to each other or to the results of the original experiment, then they try to figure out why that is so. If an experiment is not repeatable, or if the results of an experiment are not reproducible, then the scientific community will not accept the conclusions of the experiment as knowledge.

Dr. Rennab claims to have grown a turnip that, when eaten, will make the eater instantly grow two inches taller. He ate the only turnip, lost his notes on the experiment, and accidentally burned all his records. Using the terms repeatable and reproducible, explain how the scientific community will most likely react to Dr. Rennab's claim.

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Keys to Keep

- In science, a theory is a dominant explanation supported by a mountain of evidence.
- Scientific knowledge is subject to change as new information challenges existing theories.
- The scientific community reduces the effect of bias through accurate record keeping, openness with one's peers, and the replication of experiments.

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Explore It Yourself

When Ernest Rutherford discovered the structure of the atom, he couldn't actually see orbiting electrons and a central nucleus. Instead, he used his skills at **observation**, **description**, and **inference** to arrive at a model that **explained** his experimental results. You will practice these same skills in this activity.

Step 1: Get into groups of two to four students. Your teacher will give each group a box containing three objects. Do not open the box until your teacher says you can do so.

Step 2: Each person in the group should spend 2 minutes trying to figure out what is inside the box. Try different methods of gathering information: Tilt the box, shake the box, listen for sounds, feel for shifts of weight, and so on.

Step 3: On the following lines, come up with some words indicating the characteristics of each object in the box.

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Step 4: After all members have had a turn with the box and written down some characteristics, take 5 to 10 minutes as a group to discuss your findings. Each group should come to an agreement about what three objects are in the box.

Step 5: On the following lines, state the group's conclusion about what three objects are in the box. Then, say why the group made the conclusion it did about each object.

First object: ____

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Second object: ____

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Third object: ____

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Step 6: Open the box and see what objects are inside.

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What Does It Mean?

1. How did your group's conclusions compare with the actual contents of the box?

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2. People make observations with their senses. People make inferences based on observations, limited knowledge, and past experience. When were you making observations in this activity? When were you making inferences?

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3. A description communicates the qualities of an object, a process, and so on. An explanation states why an object has certain qualities, why a process happened the way it did, and so on. When were you making descriptions in this activity? When were you making explanations?

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4. Suppose that Louis, an eighth grader, has a bad stomachache. He goes to Dr. Malreaux's office to find out what is wrong. On the following lines, suggest when Dr. Malreaux might use the following skills during his examination of Louis.

Observation: _______________________________________

Inference: _______________________________________

Description: _______________________________________

Explanation: _______________________________________

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Science Practice

1. **In the late 19th and early 20th centuries, the model of the atom underwent rapid change. Why was this?**

   A. Scientists were eager to prove each other wrong.

   B. The data used to make earlier models was completely wrong.

   C. Scientists built on the work of earlier scientists.

   D. The electron microscope let scientists perform new experiments.

2. **Which of the following is <u>not</u> a way in which the scientific community minimizes bias?**

   A. by hiring people who have no biases whatsoever

   B. by checking whether an experiment's results are reproducible

   C. by ensuring that an experiment's procedures are repeatable

   D. by training scientists to be aware of their own biases

3. **How does the scientific community confirm that the work of a scientist is valid?**

   A. The most prominent scientists get together and take a vote.

   B. Scientists know that anything written in a textbook is valid.

   C. If the theory seems logical, the conclusion must be logical, regardless of the data.

   D. Other scientists carry out the same experiment to see if they get the same result.

4. **Which of the following <u>best</u> describes a scientific theory?**

   A. A scientific theory, once established, can never be changed.

   B. A scientific theory explains a broad range of observed facts.

   C. A scientific theory is a good guess made by very smart people.

   D. A scientific theory is an explanation proven beyond all doubt.

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5. Which sentence best summarizes why scientific knowledge changes over time?

A. Scientists easily change their minds about natural laws.

B. Science must explain new observations that challenge existing theories.

C. As natural laws change, scientific knowledge must change with them.

D. Scientific knowledge is a set of opinions, and opinions change over time.

6. In 1999, a team of researchers claimed that it had made a new element. Two other research teams repeated the experiment but could not reproduce the results. The original team retracted its claim.

What do these events say about the process of scientific inquiry?

A. If one team makes a finding, other teams will try to prove the finding is wrong.

B. It was impolite for the other teams to question the first team's results.

C. Physical laws change over time, so researchers cannot always replicate results.

D. Experimental results must be reproducible to be accepted as valid.

7. Which of the following is not a way that a scientific investigator can maintain credibility with other scientists and society in general?

A. present only those data that prove a hypothesis

B. share all data openly with other scientists

C. design experiments that can be replicated by other scientists

D. maintain accurate records of experiments and observations

8. The Greek philosopher Aristotle claimed that heavy objects fall faster than light ones. He did not conduct experiments to support his claim. In the early seventeenth century, the Italian scientist Galileo Galilei conducted well-documented and repeatable experiments that disproved Aristotle's claim. Explain why Galileo's experiments are considered scientific in the modern sense.

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