Communicating Your Findings It is not unusual for one scientist to continue the work of another or to try to duplicate the work of another scientist. It is important for scientists to communicate to others not only the results of the investigation, but also the methods by which the investigation was done. Scientists often publish reports in journals, books, and on the Internet to show other scientists the work that was completed. They also might attend meetings where they make speeches about their work.

Like the science-fair student in **Figure 13** demonstrates, an important part of doing science is the ability to communicate methods and results to others.

Reading Check ***Why do scientists share information?***

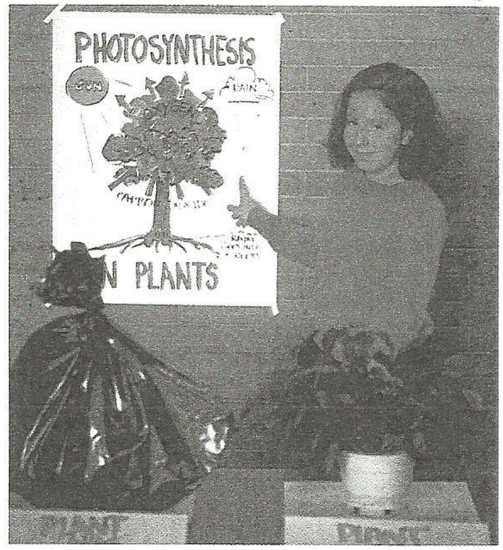


Figure 13 Presentations are one way people in science communicate their findings.

Applying Math — Make a Data Table

SEASONAL TEMPERATURES Suppose you were given the average temperatures in a city for the four seasons over a three-year period: spring 1997 was 11°C; summer 1997 was 25°C; fall 1997 was 5°C; winter 1997 was −5°C; spring 1998 was 9°C; summer 1998 was 36°C; fall 1998 was 10°C; winter 1998 was −3°C; spring 1999 was 10°C; summer 1999 was 30°C; fall 1999 was 9°C; and winter 1999 was −2°C. How can you tell in which of the years each season had its coldest average?

Solution

1. *This is what you know:* Temperatures were: 1997: 11°C, 25°C, 5°C, −5°C
   1998: 9°C, 36°C, 10°C, −3°C
   1999: 10°C, 30°C, 9°C, −2°C
2. *This is what you need to find out:* Which of the years each season had its coldest temperature?
3. *This is the procedure you need to use:*
   - Create a table with rows for seasons and columns for the years.
   - Insert the values you were given.
4. *Check your answer:* The four coldest seasons were spring 1998, summer 1997, fall 1997, and winter 1997.

Practice Problems

Use your table to find out which season had the greatest difference in temperatures over the three years from 1997 through 1999.

Science Online | For more practice, visit red.msscience.com/math_practice

Science Online

Topic: Scientific Method
Visit red.msscience.com for Web links to information about the scientific method.

Activity Identify the three variables needed in every experiment and summarize the differences between them.

Experiments

Different types of questions call for different types of investigations. Ms. Clark's class made many observations about their mystery box and about their test box. They wanted to know what was inside. To answer their question, building a model—the test box—was an effective way to learn more about the mystery box. Some questions ask about the effects of one factor on another. One way to investigate these kinds of questions is by doing a controlled experiment. A **controlled experiment** involves changing one factor and observing its effect on another while keeping all other factors constant.

Variables and Constants Imagine a race in which the lengths of the lanes vary. Some lanes are 102 m long, some are 98 m long, and a few are 100 m long. When the first runner crosses the finish line, is he or she the fastest? Not necessarily. The lanes in the race have different lengths.

Variables are factors that can be changed in an experiment. Reliable experiments, like the race shown in **Figure 14,** attempt to change one variable and observe the effect of this change on another variable. The variable that is changed in an experiment is called the **independent variable.** The **dependent variable** changes as a result of a change in the independent variable. It usually is the dependent variable that is observed in an experiment. Scientists attempt to keep all other variables constant—or unchanged.

The variables that are not changed in an experiment are called **constants.** Examples of constants in the race include track material, wind speed, and distance. This way it is easier to determine exactly which variable is responsible for the runners' finish times. In this race, the runners' abilities were varied. The runners' finish times were observed.

Figure 14 The 400-m race is an example of a controlled experiment. The distance, track material, and wind speed are constants. The runners' abilities and their finish times are varied.

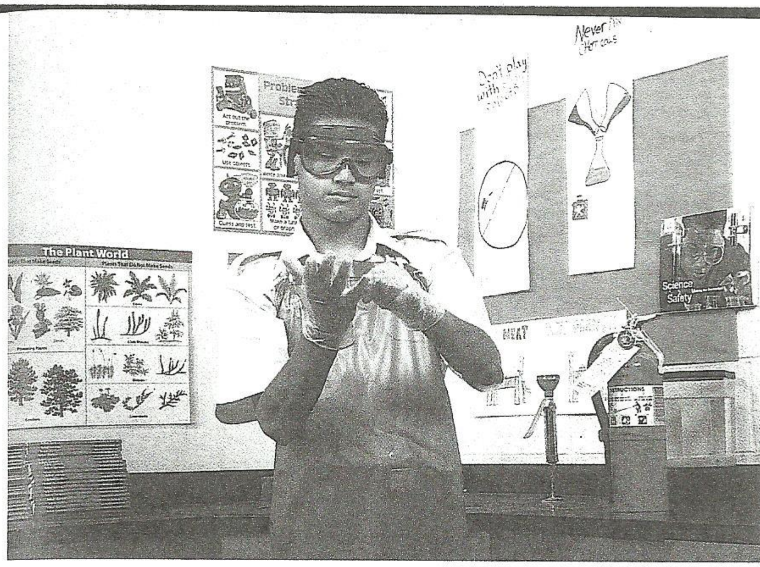


Figure 15 Safety is the most important aspect of any investigation.

Laboratory Safety

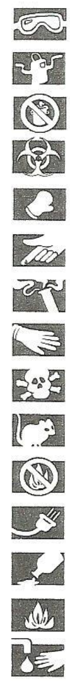
In your science class, you will perform many types of investigations. However, performing scientific investigations involves more than just following specific steps. You also must learn how to keep yourself and those around you safe by obeying the safety symbol warnings, shown in **Figure 16.**

In a Laboratory When scientists work in a laboratory, as shown in **Figure 15,** they take many safety precautions.

The most important safety advice in a science lab is to think before you act. Always check with your teacher several times in the planning stage of any investigation. Also make sure you know the location of safety equipment in the laboratory room and how to use this equipment, including the eyewashes, thermal mitts, and fire extinguisher.

Good safety habits include the following suggestions. Before conducting any investigation, find and follow all safety symbols listed in your investigation. You always should wear an apron and goggles to protect yourself from chemicals, flames, and pointed objects. Keep goggles on until activity, cleanup, and handwashing are complete. Always slant test tubes away from yourself and others when heating them. Never eat, drink, or apply makeup in the lab. Report all accidents and injuries to your teacher and always wash your hands after working with lab materials.

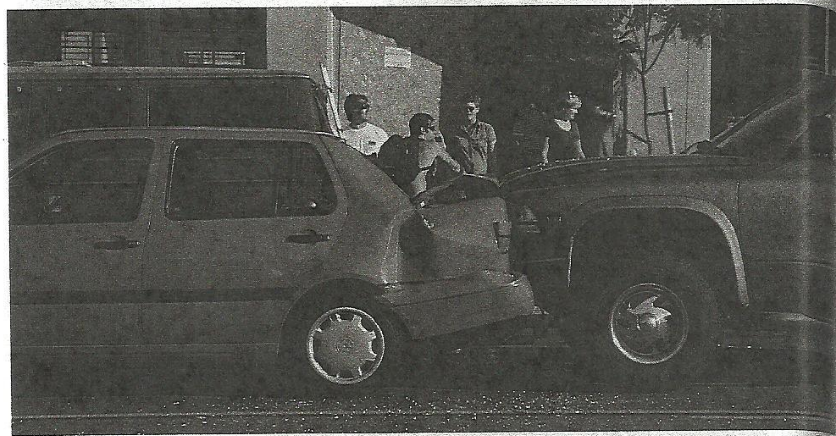
In the Field Investigations also take place outside the lab, in streams, farm fields, and other places. Scientists must follow safety regulations there, as well, such as wearing eye goggles and any other special safety equipment that is needed. Never reach into holes or under rocks. Always wash your hands after you've finished your field work.



Eye Safety
Clothing Protection
Disposal
Biological
Extreme Temperature
Sharp Object
Fume
Irritant
Toxic
Animal Safety
Flammable
Electrical
Chemical
Open Flame
Handwashing

Figure 16 Safety symbols are present on nearly every investigation you will do this year.
List *the safety symbols that should be on the lab the student is preparing to do in* ***Figure 15.***

Figure 17 Accidents are not planned. Safety precautions must be followed to prevent injury.



Why have safety rules? Doing science in the class laboratory or in the field can be much more interesting than reading about it. However, safety rules must be strictly followed, so that the possibility of an accident greatly decreases. However, you can't predict when something will go wrong.

Think of a person taking a trip in a car. Most of the time when someone drives somewhere in a vehicle, an accident, like the one shown in **Figure 17,** does not occur. But to be safe, drivers and passengers always should wear safety belts. Likewise, you always should wear and use appropriate safety gear in the lab—whether you are conducting an investigation or just observing. The most important aspect of any investigation is to conduct it safely.

section 2 review

Summary

Science Skills

- The scientific method was developed to help scientists investigate their questions.
- Hypotheses are possible explanations for why something occurs.

Drawing Conclusions

- Scientists communicate with one another to share important information.

Experiments

- Controlled experiments test the effect of one factor on another.

Laboratory Safety

- Safety precautions must be followed when conducting any investigation.

Self Check

1. **Explain** the difference between an inference and an observation.
2. **Explain** the differences between independent and dependent variables.
3. **Think Critically** A classroom investigation lists bleach as an ingredient. Bleach can irritate your skin, damage your eyes, and stain your clothes. What safety symbols should be listed with this investigation? Explain.

Applying Skills

4. **Describe** the different types of safety equipment found in a scientific laboratory. From your list, which equipment should you use when working with a flammable liquid in the lab?

Science Online red.msscience.com/self_check_quiz

section 3

Models in Science

Why are models necessary?

Just as you can take many different paths in an investigation, you can test a hypothesis in many different ways. Ms. Clark's class tested their hypothesis by building a model of the mystery box. A model is one way to test a hypothesis. In science, a **model** is any representation of an object or an event used as a tool for understanding the natural world.

Models can help you visualize, or picture in your mind, something that is difficult to see or understand. Ms. Clark's class made a model because they couldn't see the item inside the box. Models can be of things that are too small or too big to see. They also can be of things that can't be seen because they don't exist anymore or they haven't been created yet. Models also can show events that occur too slowly or too quickly to see. **Figure 18** shows different kinds of models.

as you read

***What* You'll Learn**

- **Describe** various types of models.
- **Discuss** limitations of models.

***Why* It's Important**

Models can be used to help understand difficult concepts.

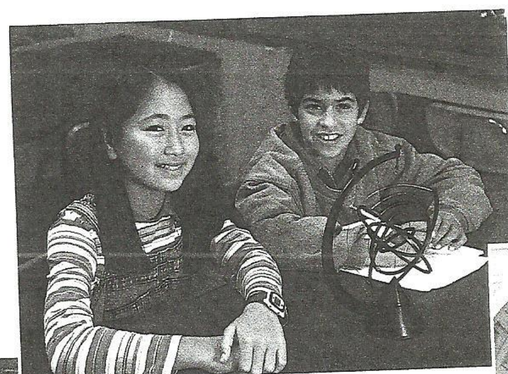
Review Vocabulary

scientific method: processes scientists use to collect information and answer questions

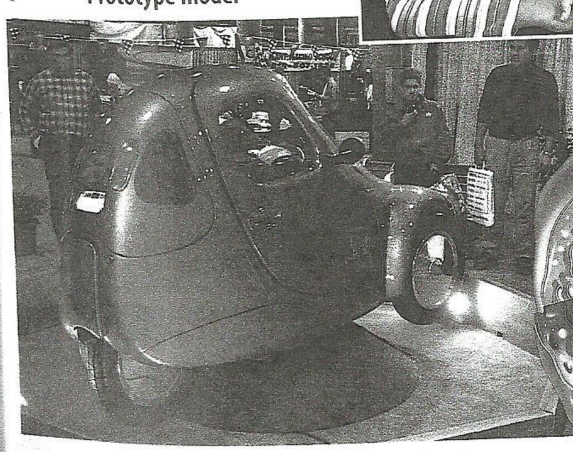
New Vocabulary

- model

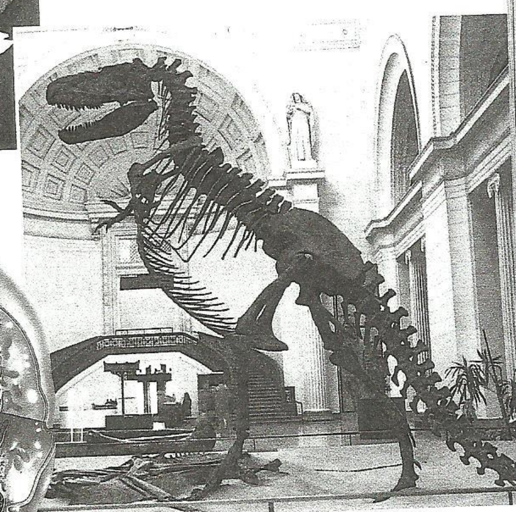
Figure 18 Models help scientists visualize and study complex things and things that can't be seen.


Solar system model

Prototype model



Cell model


Dinosaur model

Types of Models

Most models fall into three basic types—physical models, computer models, and idea models. Depending on the reason that a model is needed, scientists can choose to use one or more than one type of model.

Physical Models Models that you can see and touch are called physical models. Examples include things such as a tabletop solar system, a globe of Earth, a replica of the inside of a cell, or a gumdrop-toothpick model of a chemical compound. Models show how parts relate to one another. They also can be used to show how things appear when they change position or how they react when an outside force acts on them.

Computer Models Computer models are built using computer software. You can't touch them, but you can view them on a computer screen. Some computer models can model events that take a long time or take place too quickly to see. For example, a computer can model the movement of large plates in the Earth and might help predict earthquakes.

Computers also can model motions and positions of things that would take hours or days to calculate by hand or even using a calculator. They can also predict the effect of different systems or forces. **Figure 19** shows how computer models are used by scientists to help predict the weather based on the motion of air currents in the atmosphere.

Reading Check *What do computer models do?*

Science Online

Topic: Topographic Maps
Visit red.msscience.com for Web links to information about topographic maps.

Activity List some of the different features found on topographic maps and explain their importance when reading and interpreting maps.

Figure 19 A weather map is a computer model showing weather patterns over large areas. Scientists can use this information to predict the weather and to alert people to potentially dangerous weather on the way.

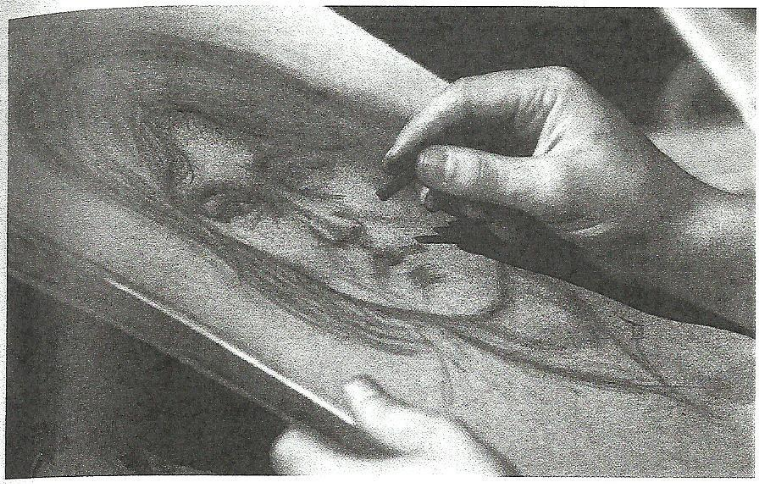


Figure 20 Models can be created using various types of tools.

Idea Models Some models are ideas or concepts that describe how someone thinks about something in the natural world. Albert Einstein is famous for his theory of relativity, which involves the relationship between matter and energy. One of the most famous models Einstein used for this theory is the mathematical equation $E = mc^2$. This explains that mass, m, can be changed into energy, E. Einstein's idea models never could be built as physical models, because they are basically ideas.

Making Models

The process of making a model is something like a sketch artist at work, as shown in **Figure 20.** The sketch artist attempts to draw a picture from the description given by someone. The more detailed the description is, the better the picture will be. Like a scientist who studies data from many sources, the sketch artist can make a sketch based on more than one person's observation. The final sketch isn't a photograph, but if the information is accurate, the sketch should look realistic. Scientific models are made much the same way. The more information a scientist gathers, the more accurate the model will be. The process of constructing a model of King Tutankhamun, who lived more than 3,000 years ago, is shown in **Figure 21.**

Reading Check *How are sketches like specific models?*

Using Models

When you think of a model, you might think of a model airplane or a model of a building. Not all models are for scientific purposes. You use models, and you might not realize it. Drawings, maps, recipes, and globes are all examples of models.

Mini LAB

Thinking Like a Scientist

Procedure

1. Pour 15 mL of **water** into a **test tube.**
2. Slowly pour 5 mL of **vegetable oil** into the test tube.
3. Add two drops of **food coloring** and observe the liquid for 5 min.

Analysis

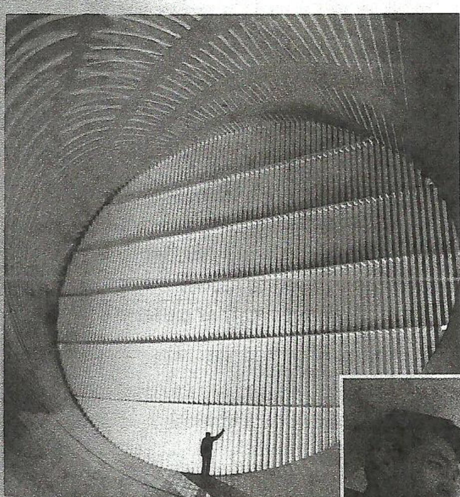
1. Record your observations of the test tube's contents before and after the oil and the food coloring were added to it.
2. Infer a scientific explanation for your observations.

Models Communicate Some models are used to communicate observations and ideas to other people. Often, it is easier to communicate ideas you have by making a model instead of writing your ideas in words. This way others can visualize them, too.

Models Test Predictions Some models are used to test predictions. Ms. Clark's class predicted that a box with a stapler in it would have characteristics similar to their mystery box. To test this prediction, the class made a model. Automobile and airplane engineers use wind tunnels to test predictions about how air will interact with their products.

Models Save Time, Money, and Lives Other models are used because working with and testing a model can be safer and less expensive than using the real thing. For example, the crash-test dummies shown in **Figure 22** are used in place of people when testing the effects of automobile crashes. To help train astronaunts in the conditions they will encounter in space, NASA has built a special airplane. This airplane flies in an arc that creates the condition of freefall for 20 to 25 seconds. Making several trips in the airplane is easier, safer, and less expensive than making a trip into space.

Figure 22 Models are a safe and relatively inexpensive way to test ideas.

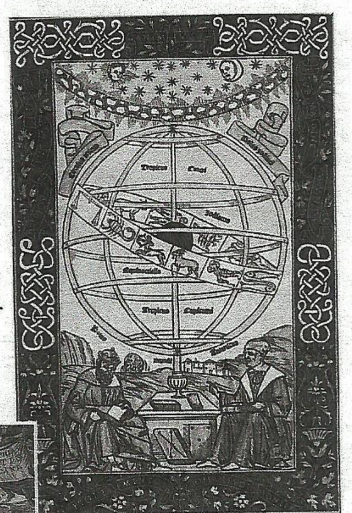


Wind tunnels can be used to test new airplane designs or changes made to existing airplanes.

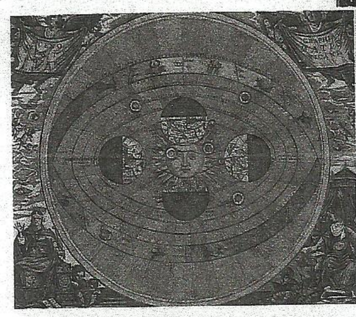
Crash-test dummies are used to test vehicles without putting people in danger.

Astronauts train in a special aircraft that models the conditions of space.

Figure 23 The model of Earth's solar system changed as new information was gathered.



An early model of the solar system had Earth in the center with everything revolving around it.



Later on, a new model had the Sun in the center with everything revolving around it.

Limitations of Models

The solar system is too large to be viewed all at once, so models are made to understand it. Many years ago, scientists thought that Earth was the center of the universe and the sky was a blanket that covered the planet.

Later, through observation, it was discovered that the objects you see in the sky are the Sun, the Moon, stars, and other planets. This new model explained the solar system differently. Earth was still the center, but everything else orbited it as shown in **Figure 23.**

Models Change Still later, through more observation, it was discovered that the Sun is the center of the solar system. Earth, along with the other planets, orbits the Sun. In addition, it was discovered that other planets also have moons that orbit them. A new model was developed to show this.

Earlier models of the solar system were not meant to be misleading. Scientists made the best models they could with the information they had. More importantly, their models gave future scientists information to build upon. Models are not necessarily perfect, but they provide a visual tool to learn from.

section 3 review

Summary

Why are models necessary?

- Scientists develop models to help them visualize complex concepts.

Types of Models

- There are three types of models—physical models, computer models, and idea models.

Making Models

- The more information you have when creating a model, the more accurate the model will be.

Using Models

- Models are used to convey important information such as maps and schedules.

Limitations of Models

- Models can be changed over time as new information becomes available.

Self Check

1. **Infer** what types of models can be used to model weather. How are they used to predict weather patterns?
2. **Explain** how models are used in science.
3. **Describe** how consumer product testing services use models to ensure the safety of the final products produced.
4. **Describe** the advantages and limitations of the three types of models.
5. **Think Critically** Explain why some models are better than others for certain situations. Give one example.

Applying Math

6. **Use Proportions** On a map of a state, the scale shows that 1 cm is approximately 5 km. If the distance between two cities is 1.7 cm on the map, how many kilometers separate them?

Science Online red.msscience.com/self_check_quiz

section 4

Evaluating Scientific Explanation

Believe it or not?

Look at the photo in **Figure 24.** Do you believe what you see? Do you believe everything you read or hear? Think of something that someone told you that you didn't believe. Why didn't you believe it? Chances are you looked at the facts you were given and decided that there wasn't enough proof to make you believe it. What you did was evaluate, or judge the reliability of what you heard. When you hear a statement, you ask the question "How do you know?" If you decide that what you are told is reliable, then you believe it. If it seems unreliable, then you don't believe it.

Critical Thinking When you evaluate something, you use critical thinking. **Critical thinking** means combining what you already know with the new facts that you are given to decide if you should agree with something. You can evaluate an explanation by breaking it down into two parts. First you can look at and evaluate the observations. Based upon what you know, are the observations accurate? Then you can evaluate the inferences—or conclusions made about the observations. Do the conclusions made from the observations make sense?

as you read

What You'll Learn

- **Evaluate** scientific explanations.
- **Evaluate** promotional claims.

Why It's Important

Evaluating scientific claims can help you make better decisions.

Review Vocabulary

prediction: an educated guess as to what is going to happen based on observation

New Vocabulary

- critical thinking
- data

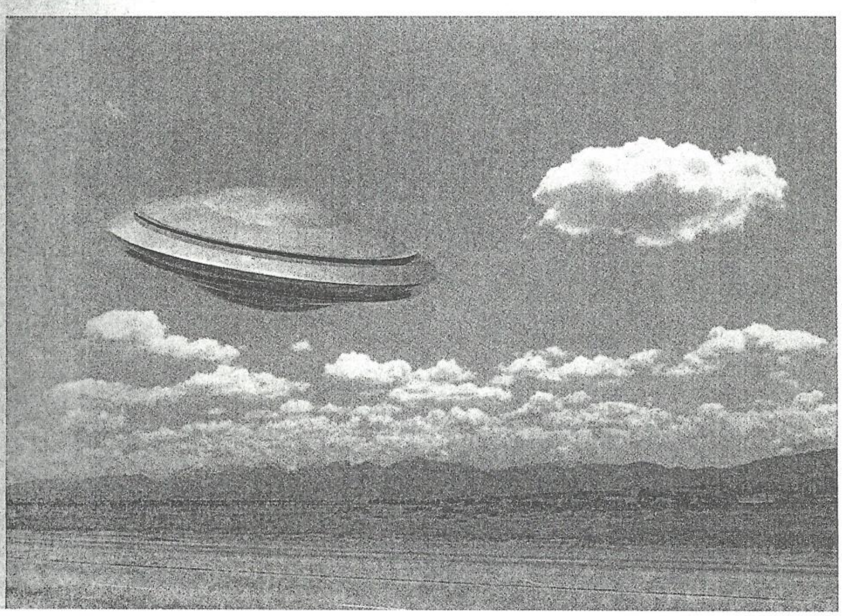


Figure 24 In science, observations and inferences are not always agreed upon by everyone. **Compare** *Do you see the same things your classmates see in this photo?*

Table 2 Favorite Foods		
People's Preference	Tally	Frequency
Pepperoni pizza	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 II	37
Hamburgers with ketchup	𝍸 𝍸 𝍸 𝍸 𝍸 III	28

Evaluating the Data

A scientific investigation always contains observations—often called **data.** Data are gathered during a scientific investigation and can be recorded in the form of descriptions, tables, graphs, or drawings. When evaluating a scientific claim, you might first look to see whether any data are given. You should be cautious about believing any claim that is not supported by data.

Are the data specific? The data given to back up a claim should be specific. That means they need to be exact. What if your friend tells you that many people like pizza more than they like hamburgers? What else do you need to know before you agree with your friend? You might want to hear about a specific number of people rather than unspecific words like *many* and *more.* You might want to know how many people like pizza more than hamburgers. How many people were asked about which kind of food they liked more? When you are given specific data, a statement is more reliable and you are more likely to believe it. An example of data in the form of a frequency table is shown in **Table 2.** A frequency table shows how many times types of data occur. Scientists must back up their scientific statements with specific data.

Figure 25 These scientists are writing down their observations during their investigation rather than waiting until they are back on land.
Draw Conclusions *Do you think this will increase or decrease the reliability of their data?*

Take Good Notes Scientists must take thorough notes at the time of an investigation, as the scientists shown in **Figure 25** are doing. Important details can be forgotten if you wait several hours or days before you write down your observations. It is also important for you to write down every observation, including ones that you don't expect. Often, great discoveries are made when something unexpected happens in an investigation.