Introduction

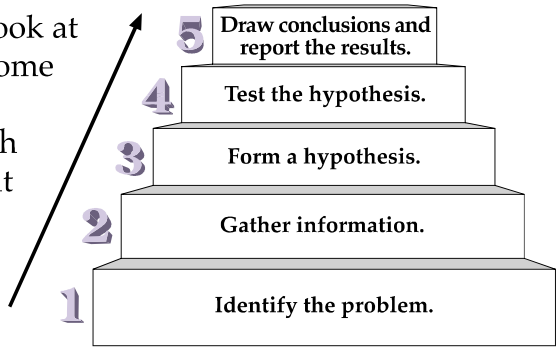
Many of us have had unanswered questions about our environment—why…? how…? when…? Some of us have gone to find answers. Most of us, however, must depend on more qualified individuals for answers. Most often, those qualified individuals are scientists—investigators in the field of science. They specialize in finding answers in an efficient and organized manner.

To investigate efficiently and in an organized way, scientists must use a certain method. This method is called the **scientific method**—a way of solving problems using specific steps. Scientists must also be careful to follow safety rules as they are conducting **experiments** in the **laboratory**. Following laboratory rules protects the results of experiments and also protects scientists from accidents.

Steps of the Scientific Method

Have you ever observed something in nature and wondered what it is and how it works? If so, you have that in common with scientists. Scientists wonder about nature. They ask questions and design experiments to find the answers to their questions.

Whenever scientists have questions or problems, they use a certain method called the *scientific method* to find answers. It is a way of solving problems using five specific steps—identifying the problem, gathering information, forming a **hypothesis**, testing the hypothesis, and drawing **conclusions** and reporting the results. The method allows scientists to look at a specific problem and develop some solutions. Using the scientific method, scientists can look at each possible solution to determine if it is correct.



Step l: Identify the problem

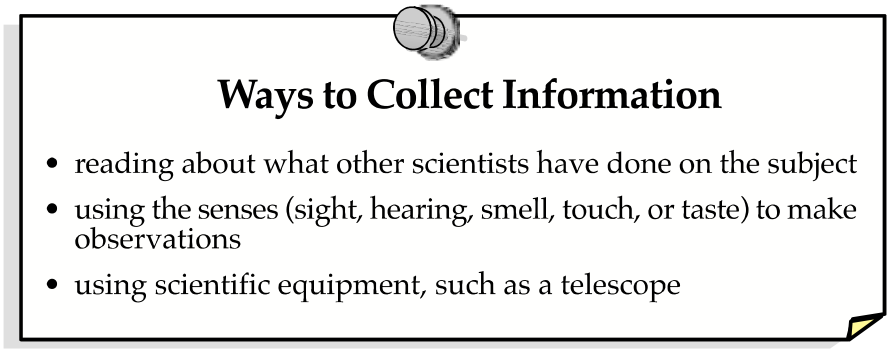
The first step is to identify the problem and develop a question about it. The study of a problem always begins with a question. Scientists must know exactly what the question is so that they can decide how they want to go about finding an answer to it.

In a study about the origins of coquina, a stone made of broken shell and bone found in Florida, scientists had only one question: How did coquina stone made from organisms that lived in the ocean come to be found miles away far from the beaches and sea?

Step 2: Gather information

Then information is collected about the question. **Observations** are made and recorded. Careful observations are important in gathering information. Scientists observe everything they can about a scientific problem. Scientists, studying various stones in areas it seemed they could not have formed, used many ways of collecting information to learn when and where the stone formed.

There are various ways to collect information. Some of the ways are listed below.

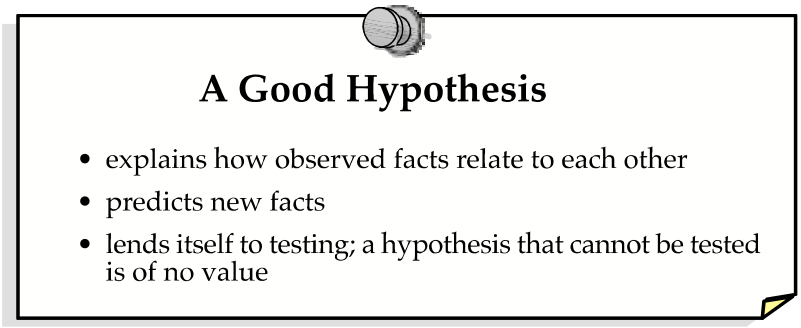


Confirmed observations can become scientific **facts**. A fact is an idea that has been proven by experiments. Observations and facts are then recorded. This recorded information becomes **data**. Scientific facts, often in the form of numbers, are called data. Scientists must use logical reasoning to interpret their data.

Step 3: Form a hypothesis

Looking at the data gathered, scientists make a guess and suggest what may be the answer to the problem. This guess, which is based on observations, is called a *hypothesis*. A hypothesis is an idea or statement that explains the relationship of observed facts to each other. It is a tool for further study of the problem. A good hypothesis must include specific explanatory information so that it can be tested.

The idea that ocean levels change was a good hypothesis for several reasons. It explained why coquina rocks were found in dry areas as well as under the sea. It predicted that the level of the ocean would not remain constant over long periods of time and could change by either spreading or receding. Very importantly, this hypothesis could be tested.



Step 4: Test the hypothesis

Scientists who proposed that the ocean levels could change would not have had a useful hypothesis if they had not found a way to test it. The test of their hypothesis was as important as the hypothesis itself.

Experimentation is the scientific testing of a hypothesis. It must be done in a careful manner. Scientists must repeat experiments many times before they accept the results. They must also test important factors under different conditions.

An experiment consists of two groups—the **experimental group** (which contains the variable being tested) and the **control group** (without the variable). The factor being tested in the experiment is the **variable factor**. A **controlled experiment** is one in which all the factors are the same except for the one being tested.

Scientists must carefully design their experiments to eliminate the possibility of bias (making their results fit their hypothesis). This is why several scientists will work together or simultaneously on the same experiment to ensure accurate results. The experiment must also be repeated many times achieving the same results in order for conclusions to be made. A single result does not imply any conclusion.

During and after experimentation, scientists must make careful and complete observations. Accurate records of the results must be made in the form of charts, graphs, or tables. Scientists use these charts, graphs,

and tables to analyze their data—to look for similarities and differences between the results. These analyses are used to help draw conclusions about their hypothesis.

Scientists developed ways to test their hypothesis that ocean levels change over time. They took precise measurements of the ocean levels.

Step 5: Draw conclusions and report the results

After the experiments are completed, conclusions are drawn. Scientists use the conclusions to reevaluate their hypothesis. They must decide if the conclusions confirm or contradict their hypothesis. An experiment does not always confirm a hypothesis. It may show the hypothesis as being partially or totally wrong. If the hypothesis is wrong, the scientist must go back and study the data and facts. The facts would be interpreted a different way, and the scientist would develop a new hypothesis to be tested. Even if an experiment supports a hypothesis, the experiment may need to be repeated many times before a hypothesis can be confirmed.

Scientists who studied the question of how and where coquina stones formed learned a great deal. After years of measuring, their conclusions stated that oceans could change and the coquina that was found on dry land could have formed in the ocean.

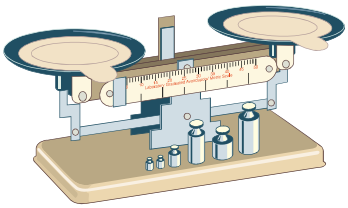
Many scientific discoveries have been made by mistakes or by forming the wrong hypothesis. Penicillin was discovered as a mold that killed all of a researcher's bacteria. Scientists often ask other scientists from different disciplines to review their research and make suggestions for refining their hypothesis or in figuring out why their hypothesis was not supported. Different conclusions may be reached by different teams of scientists working on the same problem. This difference of opinion helps the scientists reach a better understanding of the problem.

When a hypothesis has withstood the test of time, it is called a **theory**. An accepted theory, however, may change as new discoveries in science are made.

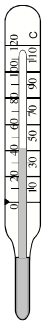
It is important to write down the results of experimentation and make them available for other scientists to use. The results may then be used to continue experimentation—to go on and make more new discoveries.

The Scientific Laboratory

Scientists are required to conduct their experiments in a very careful and precise manner. Exact measurements must be made and recorded. Making these exact measurements requires very specific equipment or scientific **apparatus**. Therefore, scientific laboratories are equipped with special apparatus for measuring and handling materials. Apparatus such as **thermometers**, scales, and **graduated cylinders** are used for measuring. Other apparatus such as **beakers**, **tongs**, **test tubes**, **funnels**, and **eyedroppers** are used for handling materials. Study the pictures of the apparatus below and learn to identify each piece by name and function.

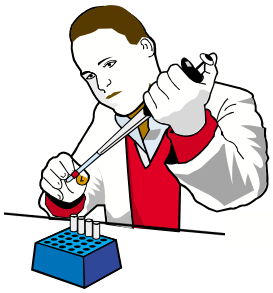


balance

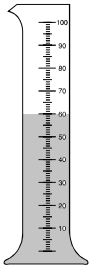


thermometer

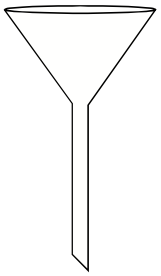
compass



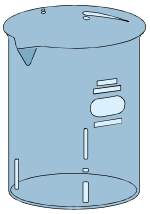
pipet



graduated cylinder

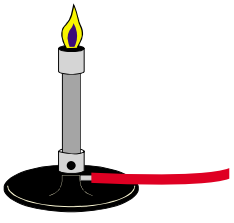


funnel



beaker

test tube



Bunsen burner

Computers and Science

Computers have become very important in scientific studies. Some experiments are performed entirely by the computer. Scientists can develop computer models or simulations to test collected data or a hypothesis. These computer simulations allow scientists to perform complicated mathematical computations more quickly and reliably. Supercomputers can perform billions of calculations per second to help solve complicated problems. Simulations are also used when the experiment may be very dangerous. Computer models help scientists refine their hypothesis and determine the type of information to be collected. Computers have helped speed up the scientific process and allow scientists to simulate past events (like the creation of the universe) or dangerous processes.

Computers also allow scientists to share information and collaborate with others doing similar research. They also allow teams of scientists from different disciplines to review or duplicate research even if they are not on the same continent. The Internet was originally developed by the Department of Defense as a means of sharing and transmitting this research data quickly. Now we use the Internet to research current scientific discoveries, to ask scientists questions about their research, or to collect data for laboratory experiments or simulations. The Internet has helped share current information among the scientific community. It is a great resource for up-to-date information. As with all other resources, however, information from the Internet must be carefully reviewed to determine accuracy and reliability.

Laboratory Safety Rules

The school science laboratory can and should be a safe place in which to explore interesting and challenging activities. There is, however, one factor that is most important—that is *safety*!

The following rules and procedures should be followed at *all* times in order to make the science laboratory a safe place.

Safety Guidelines

1. Read and follow all directions while working in the laboratory.
2. Wear protective gear, such as aprons, at all times. Wear goggles when working with dangerous or hot chemicals, or any time your teacher instructs you to do so.
3. NEVER taste or directly inhale chemicals. Test the smell of a substance by wafting or fanning some of the odor to your nose with your hand. Your teacher can show you how.
4. DO NOT bring food or drink into the lab.
5. Wash hands thoroughly after each lab.
6. DO NOT rub eyes or put hands in mouth.
7. Dress in a way that helps you work safely and efficiently in the lab. Tie your hair back. Wear cotton—it doesn't catch fire as easily as nylon or polyester. Always keep your shoes on while in the lab. Roll up long or loose sleeves.
8. DO NOT look directly down into the mouth of a filled test tube. DO NOT point the mouth of a filled test tube at another student. Liquid can splash into eyes.
9. DO NOT perform any experiments unless the instructor is in the room.
10. Report ALL minor and major accidents to your instructor. Remain calm and do not alarm others by shouting or running.
11. Know the location of the safety shower, eye wash, and fire blanket. Know how to use these important pieces of safety equipment.
12. Turn off gas burners and the gas outlets when no one is using them. NEVER leave a lit burner unattended.
13. Use tongs or gloves to handle hot objects.
14. DO NOT look directly at the sun, with or without equipment, as it may damage your eyes.
15. Keep lab tables clean and neat to prevent accidents. Wipe all areas at the end of the lab.
16. MAKE SAFETY A HABIT!

Summary

The sharing of scientific information requires that scientists be able to obtain and report their findings in an efficient and consistent manner. When answering questions, scientists use the five steps of the scientific method—(1) identifying the problem, (2) gathering information on the problem, (3) forming a hypothesis, (4) testing the hypothesis (experiment), and (5) drawing conclusions and reporting the results. Scientists must also have very specific equipment or apparatus to make accurate measurements and to handle materials properly. Just as scientists have specific rules and procedures for operating in the laboratory, we too must follow safety rules to make our experiences in the science laboratory safe and rewarding.