Scientific Method

Ck12 Science

Say Thanks to the Authors
Click http://www.ck12.org/saythanks
(No sign in required)

AUTHOR
Ck12 Science

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook®**, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform®**.

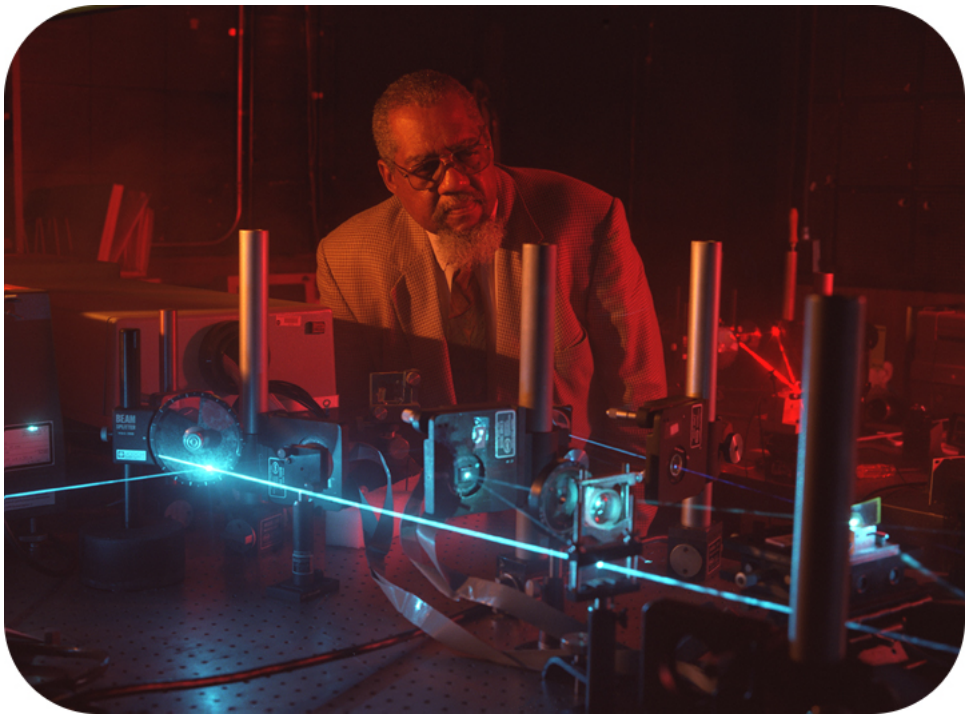
Printed: August 16, 2013

flexbook
next generation textbooks

CONCEPT 1

Scientific Method

- State the steps in the scientific method.
- Define hypothesis.
- Define theory.
- Define law.



Don Frazier, a NASA chemist, conducting an experiment using a laser imaging system.

In science, we need to make observations on various phenomena in order to either form or test hypotheses. If we can find the phenomenon occurring in nature to observe, we are fortunate – but frequently, we must "arrange" for the phenomenon to occur at a time and in a place of convenience for us – convenient because it is a place where we have all of our measuring equipment. When we cause a phenomenon to occur in order to observe it, we call the activity an experiment. We use the experiment to help verify or falsify the validity of a hypothesis. Experiments vary greatly in their goal and scale, but always rely on repeatable procedure and logical analysis of the results.

The Scientific Method

The **scientific method** is the process by which science acquires new knowledge and thus increases our understanding of the universe. To understand why the method is so important, it is useful to consider the success or lack of success of methods used to acquire knowledge about the physical world *before* the development of the scientific method. One major method used was reliance on authority. This may have been the authority of a church, government, or particular individuals known to be very intelligent (such as many of the ancient Greek philosophers).

Prior to the invention of the scientific method, people based their actions on explanations of the physical world provided by authorities. When these activities failed because the explanations were incorrect, many people began seeking other explanations. An early case of reliance on authority proving incorrect was when Galileo's disproved

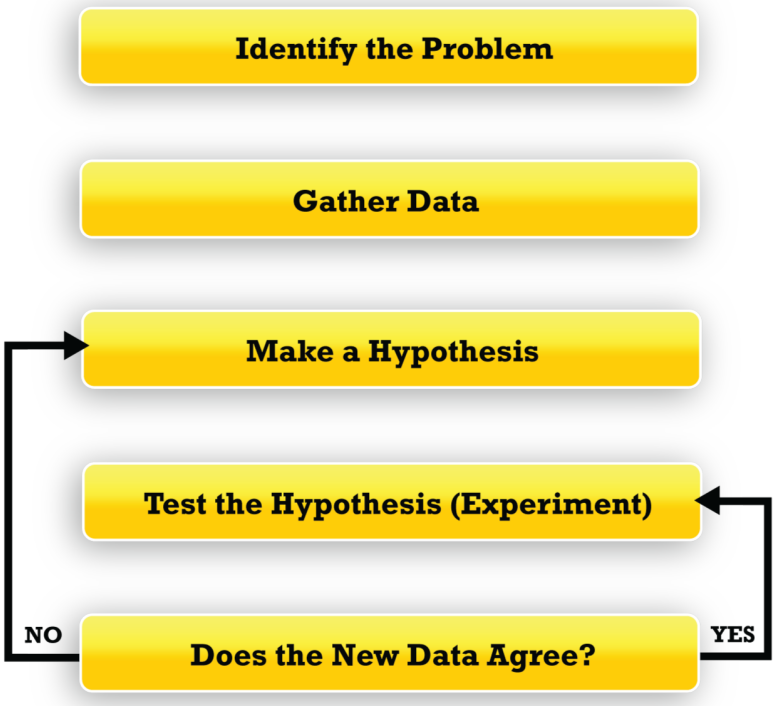
Aristotle's ideas about falling objects (as discussed in the introduction to this chapter). Reliance on authority did not produce a successful result, but observation of nature did.

In another failure of relying on authority, one particular church said that the earth was the center of the universe and did not move. It was also Galileo who proved this concept false, though it nearly cost him his life. Authorities were also incorrect when leaders claimed that smallpox could be avoided by making loud noises, such as with bells and cannons. Hundreds of thousands of people died of smallpox while the bells and cannons boomed away.

Scientists could see that authority, opinion, and superstition were keeping seekers from discovering how the physical world truly functioned. Over many years, a procedure was devised that produced greater success. Using the new method, astronomers could correctly predict where individual stars would be on a given night. The process of vaccination was discovered, saving millions of lives. The sciences of chemistry, physics, and biology began to move ahead. Using the scientific method, mankind has learned more about the physical world in the last 200 years than was learned in the previous 5000 years.

Once the **scientific method** was devised, the *observation* of nature was revealed the key to true understanding of nature. All theories must be consistent with observations of the phenomenon in question. Of course, it goes without saying that accurate observations must be recorded without fear or favor. Scientists cannot allow public opinion or governmental pressure to affect the recording of observations.

Even though some of the steps do not occur at all, and sometimes the steps occur in a different order, it is still worthwhile to list the steps in the scientific method.



Three very important points about the scientific method are:

1. Experimental data/results must be reproduced and verified by other scientists.
2. Theories must agree with all observations made on the phenomenon under study.
3. Theories are continually tested . . . forever.

The scientific method involves making observations on the phenomenon being studied, suggesting explanations for

the observations, and testing the suggested explanations (also called **hypotheses**) by making new observations. Hypotheses are a sort of first guess in terms of explanations for observations.

After many **experiments** and tests in which results support the hypothesis, the hypothesis gradually becomes a **theory**. Theories remain theories forever and are constantly retested with every new observation. Theories never become "facts" or **laws**.

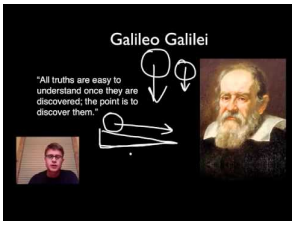
In science, a law is a mathematical relationship that is determined to exist between observations under a given set of conditions. The gas laws are excellent examples of scientific laws. The gas laws are mathematical relationships that exist between the pressure, volume, and absolute temperature of a gas under certain conditions. There is a very fundamental difference between observations of the physical world and explanations of the nature of the physical world. Hypotheses and theories are explanations, whereas laws and measurements are observational.

Summary

- Early methods of learning about the physical world, including reliance on authority, opinion, and superstition were unsuccessful.
- The scientific method was successful in helping humankind begin to effectively understand the physical world.
- The scientific method consists of making observations, suggesting a possible explanation (hypothesis), testing the hypothesis with new observations, making a new hypothesis if the new observations contradict the old hypothesis, or continuing to test the hypothesis if the observations agree.
- A hypothesis is a tentative explanation that can be tested by further observation.
- A theory is a hypothesis that has been supported with repeated testing.
- A scientific law is a statement that summarizes the results of many observations.
- Experimental data must be verified by reproduction from other scientists.
- Theories must agree with all observations made on the phenomenon under study.
- Theories are continually tested . . . forever.

Practice

Use this resource to answer the questions that follow.



MEDIA

Click image to the left for more content.

1. Which two Greek philosophers are mentioned in the video?
2. Which scientist disproved Aristotle's idea that heavy objects fall faster than lighter objects?

Review

1. A scientific investigation is not valid unless every step in the scientific method is present and carried out in the exact order listed in this lesson.
   (a) True
   (b) False
2. When a theory has been known for a long time, it becomes a law.

   (a) True
   (b) False

3. Which of the following is closest in meaning to the word “hypothesis”?

   (a) Fact
   (b) Law
   (c) Formula
   (d) Suggested explanation
   (e) Conclusion

4. Why do scientists sometimes discard theories?

   (a) The steps in the scientific method were not followed.
   (b) Public opinion disagrees with the theory.
   (c) The theory is opposed by the church.
   (d) Contradictory observations are found.
   (e) Congress voted against it.

5. If a hypothesis is rejected by the observations from an experiment, then the experiment

   (a) May have been a success.
   (b) Was a failure.
   (c) Must have been poorly designed.
   (d) Didn’t follow the scientific method.

- **scientific method:** Consists of making observations on the phenomenon needing explanation, suggesting a possible explanation for the observations (hypothesis), testing the suggested explanation with new observations, make a new hypothesis if the new observations contradict the old hypothesis, or continue to test the hypothesis if the observations agree.
- **hypothesis:** A tentative explanation that can be tested by further observation.
- **theory:** A hypothesis that has been supported with repeated testing.
- **law:** A statement that summarizes, often as a mathematical relationship, the results of many observations.
- **experiment:** When we cause a phenomenon to occur in order to observe it, we call the activity an experiment. We use the experiment to help verify or falsify the validity of a hypothesis.

References

1. Courtesy of NASA. http://www.nasa.gov/centers/marshall/about/marshallfaces/frazier.html. Public Domain
2. CK-12 Foundation - Christopher Auyeung. . CC-BY-NC-SA 3.0