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PURDUE EXTENSION

# The Scientific Method

**What is the scientific method?**

The scientific method provides an organized way to think about and solve problems based on data. Most scientists describe it as the following steps:

1. **State the problem.** State the problem that you will study as clearly and concisely as possible.

2. **Form the hypothesis.** Describe what you think the result of your study will be.

3. **Observe and experiment.** Observe or set up an experiment to test your hypothesis. Tally your data.

4. **Interpret data.** Once you have collected your data, you must understand what it tells you. The data can be interpreted by comparing numbers visually and/or in graphic form.

5. **Draw conclusions.** Did your observations and/or experiments support your hypothesis? Was your hypothesis proved or disproved by your study? Did your results show a strong correlation? Were there things that could be changed to make a better experiment? Are there things that need to be studied further?

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**What if the hypothesis is disproved?**

The scientific method requires that a hypothesis be ruled out or modified if its predictions are clearly and repeatedly incompatible with experimental tests. Hypotheses are subject to researcher bias and misinterpretation, but proper observation and experimentation minimize the risk of error. Beginning researchers make a few common mistakes. The most fundamental error is to mistake the hypothesis for an explanation of a phenomenon without performing experimental tests and following all the steps outlined above. Another is to ignore or rule out data that do not support the hypothesis. The failure to identify widespread numerical or logical errors is another mistake.

**What are the difference between a scientific hypothesis, theory, and law?**

A *hypothesis* refers to an educated or reasonable guess based on what can be observed or known. In other words, it's a statement that can be tested and collaborated or disproved. A hypothesis can be further supported or disproven at any time with an experiment or a new observation. If the hypothesis is disproved, the researcher develops a new hypothesis that incorporates the new knowledge from the experiment. A hypothesis is generally based on previous experiments and answers a scientific question. Numerous scientists working on the same problem often test the same hypotheses, so sharing experimental methodology is extremely important.

A *theory* refers a hypothesis that has been supported with repeated testing, generally by multiple scientists. A theory holds until there is evidence to dispute it. It is usually a general principle that was defined to explain a phenomenon and supported by repeated

experiments. A theory can be refined or improved by new data or observations. Theories are generally accepted as being true in the scientific community.

A *scientific law* refers to a relationship (often mathematical) that has been shown to be consistent across time and space and has never been disproved. There are no exceptions to scientific laws. Scientific laws must be universal and are the foundation of science. If a scientific law is proven wrong, any other research based on that law is invalidated. There are very few things in the field of science that ever get truly defined as scientific laws.

**Examples**

*Hypothesis:* You observed that the road is wet, so you form a hypothesis that it has rained. Through checking a rain gauge, the hypothesis can be proven or disproved.

*Theory:* general relativity

*Law:* the laws of thermodynamics, Boyles's law, and Maxwell's laws of electromagnetism.

**What does it mean for a paper to be published in a peer-reviewed journal?**

Science advances because researchers share they knowledge they have gained through research. It is expected that scientists and engineers share what they have learned with their colleagues. This involves writing a paper, article, bulletin, or other informational piece and submitting it for review by others working in the same area. Once an article has passed review by multiple unaffiliated researchers (commonly three), it is considered peer-reviewed and is recommended for publication to be shared with others working in the specific area.

Readers of peer-reviewed publications can assume that the research is valid, because other researchers have reviewed it.

**What's in a peer-reviewed journal?**

- The content makes a contribution that advances the state of the art in the topic.
- The content has relevance (e.g., experimental methodology, scientific discipline) to the publishing source.
- The content is presented clearly, with as many details as possible for reproducibility by a researcher. (Note: if the information is not reproducible, it is not considered research.)
- The content presents accurate and complete results.
- The content includes a clear conclusion or discussion and suggestions for future work or research.

**Resources**

University of Rochester. Appendix E: introduction to scientific method. (Retrieved March 10, 2014 from http://teacher.nsrl.rochester.edu/phy_labs/appendixe/appendixe.html)

Fayetteville-Manlius High School. What are the differences between hypotheses, theories, and laws? (Retrieved March 10, 2014 http://www.fmschools.org/highschool.cfm?subpage=3765)

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