Name: _____
Period: _____
Due Date: _____

# The Limits of Science

## Introduction

Science is a powerful tool. It provides a structure for looking at nature using our senses to explain our observations. But science also has its limits.

## Limitations of Science

- Science must follow distinct rules.
- Science can only solve specific types of problems.
- Science can only use certain types of explanations.
- Scientific solutions are only attempts to explain nature. They are not facts.
- Science can be misused.
- Science can be done poorly.

## The Rules of Science

Science must follow certain rules. All people involved in scientific exploration and discovery adhere to these rules. Ignorance about these 'Rules of Science' has led to much confusion about the nature of science and what science can and can't do. This in turn has led to the misuse of science in advertising, religion, and politics.

***Four Important Rules of Science***

1. Science cannot answer questions that require opinion, beliefs, or judgment as part of the answer.
2. Supernatural forces cannot be used as part of a scientific explanation.
3. Scientific explanations must be based on careful observations and the testing of hypotheses through experimentation.
4. It must be possible to *disprove* a hypothesis.

## Questions Science Cannot Answer

Science cannot solve all problems. A basic assumption of science is that the laws of nature are the same everywhere. Those physical laws do not depend on opinion. People, however, have different customs, beliefs, and life styles. Many human questions require the use of opinion. For example:

- *"What is right?"*
- *"Who was the best president?"*
- *"Which religion is best?"*
- *"What is the purpose of human existence?"*

All of these questions require judgment or opinion to answer. Since the answers will be based on opinion, science cannot provide answers to such questions. Other areas of human thought, such as philosophy and religion, do deal with these questions.

Science was never meant to answer questions about matters of judgment, opinion, or belief. This is a key rule of scientific study. Science was developed to answer questions only about how nature works, based on physical observations (data).

## Explanations Science Cannot Use

A hypothesis is a possible explanation to a question about nature. It must always be possible to *disprove* a hypothesis. This is also a critical rule of scientific inquiry. *Explanations which are impossible to disprove cannot be used in science.*

***Some Explanations Impossible to Disprove***

- Some of our behavior is caused by mysterious forces from the planets or stars.
- The origin of all of life forms was through God's creation.
- Some people can predict the future because they have a special ability.

A common feature of these explanations is that they require mysterious or **SUPERNATURAL FORCES.** A **supernatural force is a power which can do anything; the laws of the universe do not apply.** Such forces are not limited by the laws of nature, therefore, their actions cannot be predicted, or experimented on. To be able to disprove an explanation, we must be able to test it. This means, in science, we must be able to do an experiment.

Experiments to test a hypothesis must be carefully designed. The test must give a predictable result if the hypothesis is correct. If the hypothesis is incorrect, the results must be clearly different from the predicted result.

Supernatural forces may very well exist. Many people believe they do. But supernatural explanations do not give us predictable actions. Therefore, they cannot be used in any scientific way. **Scientific explanations can never include supernatural or mysterious forces to explain phenomena.**

## Scientific Solutions Are Not Facts

**The main goal of science is to understand nature by developing predictive theories, not to collect or produce facts.** The scientific method is a very successful process for uncovering cause and effect problems. It has given us a reliable, workable picture of the real world. As a result, many people assume that a **SCIENTIFIC EXPLANATION** is a fact. This isn't so. An explanation is formed through observation and interpretation by rational thought (deductive and inductive reasoning.)

**Facts** are observations about nature generally accepted as true. They serve as evidence for or against theories. Although facts sometimes turn out to be wrong, such as: the sun circled the earth and species never change, we're usually pretty confident about whether something is a fact. For example, it's a fact that life has changed over time; that species once living are now extinct and that new species have taken their places.

**Scientific theories** are not facts. They are sets of statements, often called postulates, that explain facts and predict new facts. Newton's gravitational theory is a good example of a scientific theory. All good scientific theories have these characteristics:

- Theories have to be **economical,** they must explain much in few words.
- Theories must be **general,** a theory that requires a different postulate for every fact is useless. On the other hand,
- every theory is **limited** in scope; no scientific theory explains every imaginable fact.

- Theories must be **falsifiable;** we must be able to imagine some condition that, if true, would prove the theory wrong.

Good theories make specific predictions about what will and what will not happen in certain conditions. A theory that makes wrong predictions is false. A *prediction*, in science, means logical deduction, not wildly forecasting the future.

***Scientific Explanations***

**Hypothesis:** a possible explanation to a question about nature, based on observation.

**Theory:** a set of statements that explain and predict facts. They are economical, general, limited, falsifiable and predictive.

A "theory" as the word is used in common everyday English means just a possible idea. This is not how the word theory is used in science. **Scientists consider a theory to be very solid, and strongly supported by research and evidence over time.** For example, Einstein's Theory of Relativity has been upheld by research data over a period of 70 years and Darwin's Theory of Evolution by Natural Selection has been supported by a wide variety of research for over 140 years.

## Observations and Facts in Science

Observations and facts involve what our physical senses tell us about the world. More than one possible explanation can be derived from the same observation, depending on the experience, knowledge and bias of the observer.

***The Difference Between Observation & Fact***

**Observation:** any information received directly by seeing, hearing, smelling tasting or touching (or through technological tools that extend our 5 senses).

**Fact:** an observation that appears the same to all careful observers, and therefore assumed to actually exist in nature.

**Scientific explanations are attempts to describe how nature works, not to discover "the truth."** Scientific explanations may be considered as likely to highly probable. But, *scientific explanations are never a certainty.* There is always a chance that what was believed to be accurate could be disproved with additional evidence, observation and experimentation. Hypotheses and scientific theories are therefore clearly not facts. They are merely our efforts to understand the workings of nature based on facts.

## The Misuse of Science: Pseudoscience

Some groups of people falsely claim that science has proven their beliefs to be "true." Any belief system that misuses science or claims to utilize scientific methodology to verify itself is called pseudoscience. Believers of a pseudoscience may attempt to do scientific studies to support their beliefs. They may also refer to other studies that only seem to support their belief system, and reject evidence that doesn't bolster their belief system.

**Comparison of Pseudoscience and Science**

| *Pseudoscience* | *Science* |
|---|---|
| • Ignores certain rules of science. | • Follows the rules of scientific inquiry. |
| • Tries to prove own explanations. | • Tries to disprove own explanations. |
| • Includes supernatural forces in interpretations. | • No supernatural forces used in interpretations. |
| • Ignores or discounts contradictory research. | • Includes all related research, even if it does not support their interpretations. |

When a pseudoscience is examined closely, certain rules of science are always missing. For example, supporters of a pseudoscience usually seek to prove their point of view, and do not undertake serious efforts to disprove it.

Proponents of pseudoscience also often use supernatural or mysterious forces as explanations of phenomenon. In addition, a belief in those forces is assumed as a required part of the explanation. These are clearly not acceptable procedures for scientific inquiry. Nevertheless, such groups usually keep claiming that their beliefs have been "proven" scientifically.

***Examples of Pseudosciences***

- ESP (Extra Sensory Perception)
- Astrology
- Biorhythms
- Hauntings/Ghosts
- Scientific Creationism
- UFO Studies
- Numerology
- Crystal Healing
- Tarot Cards

Pseudoscientific topics have often been studied carelessly. Poor scientific techniques were used or scientific rules were ignored. **The claims of pseudoscientific adherents have never been supported by the results of controlled scientific studies.**

## Good Science vs. Poor Science

**Some science is not reliable because it's poorly done.** As you know, not everyone does a job well. The music played by some musicians sounds off-key. Some mechanics can't always repair a car properly. Some secretaries write letters with misspelled words. Likewise, some scientists may do poor research.

Sometimes, scientists may not be careful. Errors might be made in measurement or interpretation. Or, the experimental design may neglect to control important variables. These factors might be the real cause for the experimental results, and not be discovered.

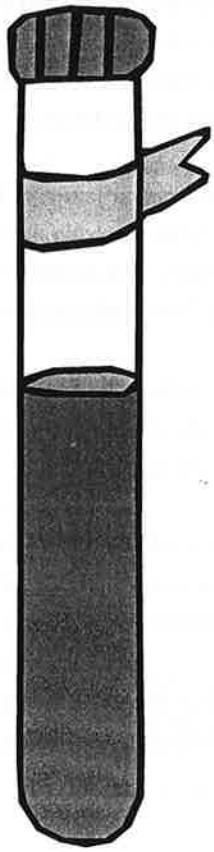
Scientists also have bias, as do all humans. They may be prejudiced toward a hypothesis and ignore bits of data which indicate an alternative interpretation. Properly designed experiments control researcher bias by using large test groups, controls, double-blind experiments and placebos.

## Guidelines For Good Science... The Rules of Inquiry

1. **Controlled:** Only one variable at a time is tested experimentally.
2. **Repeatable:** Different scientists should be able to repeat the procedures, and get the same results.
3. **Cause-Effect:** Does "X" cause "Y" to happen? If so, a change in one must result in a matching change in the other. A large test group is used.
4. **Species-Specific:** Experiments with one type of plant or animal may not give the same results with other types (i.e., rats & humans).
5. **References:** All earlier studies of the problem should be considered and related to the present study.
6. **Published:** Research should be printed in reputable journals where they can be studied and repeated by other scientists. References to unpublished studies should be questioned.

Testing a hypothesis many times, in a myriad ways, by numerous scientists is one of the strengths of science. Errors made by one scientist would very likely be found and corrected by the other scientists. This system works well to make scientific conclusions more reliable. However, these conclusions are always subject to change based on new information and research. Scientific conclusions are not static, but are constantly under revision.

If a scientist makes many mistakes, his or her reputation will suffer. Other scientists may be suspicious of all studies published by these careless scientists. They may double check the studies, publicly criticize the work, or ignore it completely. Some science is not reliable because it is done in a shoddy or even dishonest manner. Working scientists may be in competition with each other for limited financial support from governmental grants and by private industry. Often scientists feel the need to produce "results" so that their funding will continue. For example, the National Geographic sponsors hominid fossil hunting trips to Africa. If the paleontologist come back empty-handed after a 6-month season, they are less likely to be funded again.



At times, the results of poor science will fit what someone else wants to see. This might be a politician or businessman who may not understand science. The experimental results may be used in misleading advertising, or to produce new laws. Due to these problems, many people have come to distrust science. This distrust stems from lack of understanding about the nature and goals of scientific research. Remember, science cannot solve all human problems, nor can "breakthroughs" be made on demand.

*Note that both science and non-science produce practical applications. Since this is a science class, we will be concentrating on the study of "scientific inquiry," i.e., good experimental design, research techniques and analysis based on evidence.*

Name _____ Period _____ Due Date _____

## Limits of Science: Activity & Inquiry for Inquisitive Science Students

1. **Read** the research sample below, and each of the 5 features listed below it.
2. If you think a feature is an example of "good" science, write **GOOD** next to that number. **For each** "GOOD" science example indicate which guideline of "good science" was followed, from the reading "Guidelines for Good Science… The Rules of Inquiry."
3. If you think it is a feature of "poor" science, write **POOR** next to that number. **For each** "POOR" science example, indicate which guideline of "good science" was not followed.

***Sweet Research Sample***

A number of years ago, an artificial sweetener called "cyclamate" was legally banned. As a result of certain research results, no more cyclamate could be sold in the United States. Listed on the chart are some of the features. Using the information from the 'Limits of Science' reading, answer questions 1–12 using articulate and complete sentences.

| Research Feature | Good/Poor? | Guideline for Good Science |
|---|---|---|
| 1. Mixtures of cyclamate and saccharin (another artificial sweetener) were fed to 240 rats during their lifetimes. Tumors were found in 7 of 20 males and 1 of 30 females. It was concluded that cyclamate was responsible for the tumors. | | |
| 2. Different amounts of the mixtures were used, but only the rats receiving the highest dosage level developed tumors. The amount was equivalent to a person drinking 350 bottles of diet drink per day. | | |
| 3. According to some unpublished results of another study, chick embryos developed abnormally when given cyclamates. | | |
| 4. None of the several published studies on the effects of cyclamates on mammals have shown any abnormal embryo development. | | |
| 5. From the above observations, the FDA scientists concluded that cyclamates could be harmful to humans. | | |

## Activity 5.4 (8 of 10) *Student Handout* (7 of 7)

**Using the information from the "Limits of Science," answer the following questions, using articulate and complete sentences.**

1. Of the six limitations of science, which do you think is most often ignored? Explain why. Use examples from your own reading and experience.

2. Why can't supernatural forces be used in a scientific explanation?

3. What does science assume about the laws of nature?

4. What kinds of questions can NOT be answered by science? Write two such questions of your own.

5. What must always be possible to do to a hypothesis? State a scientific hypothesis of your own.

6. What is the main goal of science? Does this differ from your previous understanding? How?

7. What are the key attributes of a scientific theory? How does "fact" differ from observation?

8. What do all types of pseudoscience have in common? Why are people so attracted to pseudoscience? Do you have a personal pseudoscientific favorite, why?

9. What three scientific "rules" are usually ignored by pseudoscience?

   a.

   b.

   c.

10. Why are scientific theories so reliable and predictive?

11. What are some characteristics of poorly done science?

12. Funding for many scientific studies here in the United States is provided by private companies (e.g., drug companies developing a new product), or by intense competition through the government in the form of grants. Does this method of financing science make an impact on the way the researches perform their experiments? Explain.