The Scientific Method

What is science?

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"Science is a way of trying not to fool yourself."
– Richard Feynman

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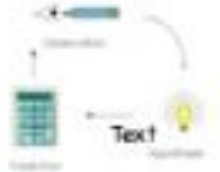
The Scientific Method



1) Unending process

2) Interplay of theory & observation

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The Scientific Method

Application

- Observation: *The car won't start.*
- Hypothesis: *The battery is dead.*
- Prediction: *If I connect a fresh battery, the car will start.*

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Practice Question

Q. What is the last step in the Scientific Method?

A. Observation

B. Hypothesis

C. Publication

D. There is no last step; it is an unending process.

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"All that we can hope to do is to leave behind us Observations that may be confided in, and to propose Hypotheses which after Ages may examine, amend or confute." – Edmund Halley (1656–1742)

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Scientific Theories

"Theory" in common speech

An unproven idea—probably an erroneous one.

"Theory" in science

A theory is an explanation of a phenomenon in nature in terms of simpler ideas—an explanation that enables one to make predictions that can be tested.

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Theories: true, false, and ?

- The Special Theory of Relativity —*true*
- The Earth-centered Theory of the Solar System—*false*
- String Theory — *maybe, maybe not*

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Testability of Theories

Scientific Theories are Testable

Testable means that they can be proved wrong.

Example 1

The Earth is the center of the solar system.

Example 2

There are other universes which exist in parallel with our universe.

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Testability

People think scientists try to prove their theories right. Which is easier...

A) proving a theory right.

B) proving a theory wrong.

Comment: "Scientific theories can be disproved, but never proved 100%."

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Practice Question

A scientific theory is...

A. A well-established fact.

B. A doubtful idea.

C. A hypothesis that makes testable, useful predictions.

D. A really dumb idea.

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Are Theories Ever Correct?

- 1000 BC: The Earth is flat.
- 300 BC: The Earth is a sphere.
- 1800 AD: The Earth is a flattened sphere (oblate spheroid).
- 2000 AD: The Earth's surface is irregular.

- Example: the theory of gravity.

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Good Theories

A good scientific theory...

...is testable.

...enlightens us.

...works.

...raises new questions.

...although it's not necessarily "true."

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Practice Question

Q. An essential characteristic of a scientific theory is that:

A. It has been proved true.

B. It can be proved true.

C. It can be proved false.

D. All scientists agree upon it.

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Newton's Rules of Science

Principia (1686)

1. *Scientific theories should not try to explain more than what we observe in nature.*
2. *The same effects arise from the same causes.*
3. *The properties of things and the laws of nature are universal.*
4. *The simplest hypothesis that accounts for the observations should be held true "or very nearly true" until contradicted by observation. (Occam's Razor)*

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Practice Question

Scientists prefer theories that are…

A. As simple as possible.

B. As complex as possible.

C. Not falsifiable.

D. Elegant but not useful.

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Thoughts about science

Know more about the world today than you did yesterday.

Lessen the suffering of others.

https://www.youtube.com/watch?v=ZEFPgyytkHo

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Pseudo-science

- **Pseudo-science:** schools of thought that may appear to be scientific, but are not.
  - *Pseudo* = false
- Examples
  - *Magical healing*
  - *Palmistry*
  - *UFOlogy*
  - *Mars Face*

"Where is McDonalds going to get here?"

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Pseudo-science vs science

1. A pseudo-science makes claims that
   - are unfalsifiable, or
   - are testable but are not tested scientifically, or
   - have failed testing but the failure ignored.
2. The predictions of a pseudo-science lack theoretical explanation.

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Objective vs. Subjective

The predictions are "verified" by subjective rather than objective means.

Objective

Based on observable fact.

Something everyone can agree upon.

Subjective

Open to personal interpretation.

Something people have different viewpoints about.

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Hume's Maxim

"No testimony is sufficient to establish a miracle, unless the testimony be of such kind, that its falsehood would be more miraculous than the fact which it endeavors to establish."—David Hume (1711-1776)

"Extraordinary claims require extraordinary evidence."

—Carl Sagan (1934-1996)

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Pseudoscientific Thinking

1. Anecdotes (stories) aren't proof.
2. Scientific jargon does not science make.
3. Heretics don't have a special insight.
4. Unexplained isn't inexplicable.
5. Coincidence is not cause and effect.
6. The burden of proof is on the heretic.

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UFO

What is the most likely explanation for these images?

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UFO

What could this be?

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Practice Question

Q. Pseudo-science differs from science in that:

A) Science is always right.

B) Pseudo-science doesn't use the Scientific Method.

C) Pseudo-scientists are open-minded.

D) Science can't study the para-normal.

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Skepticism

Skepticism, like chastity, should not relinquished too readily.
–George Santayana (1863-1952)

The wisest mind has something yet to learn.
—Santayana

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Hypatia's Admonition

"Reserve your right to think, for even to think wrongly is better than not to think at all. To teach superstitions as truth is a most terrible thing."

—Hypatia (400 AD)

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