

The Scientific Method

How would you define the "scientific method"?

The Scientific Method

1. **Observation** - collecting information (data)
2. **Question** - formulating a question (*often* from the observation)
3. **Hypothesis** - forming a possible explanation of the question
4. **Testing** - testing the hypothesis by collecting more data
5. **Results** - interpreting the results of the test and deciding if the hypothesis should be rejected. The hypothesis is rejected if the results contradict it, showing it is wrong.
6. **Conclusion** - stating a conclusion that can be evaluated independently by others.

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An example

1. **Observation** - collecting information (data)

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An example

2. **Question** - formulating a question from the observation

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An example

3. **Hypothesis** - forming a possible explanation

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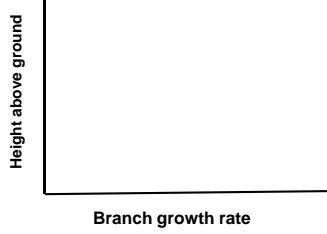
An example


4. Testing - test the hypothesis by collecting more data.

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An example


4. Testing - test the hypothesis by collecting more data.



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An example

5. Results - interpreting the results of the test and deciding if the hypothesis should be rejected.

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An example

6. Conclusion - stating a conclusion that can be evaluated independently

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Does the classical “scientific method” capture all of how science really works?

Not all science begins with observation

- **Practical questions**
 - ✓ Applied disciplines (forestry, agriculture, restoration, etc.)
- **Theory-driven inquiry**
 - ✓ High energy physics, global change, etc.

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Some ideas & historical context: from Bacon to Babies

Science & logic in ancient cultures (e.g., Greeks, Chinese)

Sir Frances Bacon (16th century) – **Hypothetico-deductive method**

Hypothesis & testing of predictions that follow from the hypothesis

Deduction of a generality from the specific results (“induction”)




wikipedia

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From Bacon to Babies

Sir Frances Bacon (16th century) – [Hypothetico-deductive method](#)

Karl Popper – (early - mid 1900s) [Hypothesis falsification](#)
Austro-British historian & philosopher of science



Hypotheses are never proven – only disproven
(details next week)

wikipedia

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From Bacon to Babies

Sir Frances Bacon (16th century) – [Hypothetico-deductive method](#)

Karl Popper – (early 1900s) [Hypothesis falsification](#)


John Platt – (1964) [Strong inference](#)

The importance of multiple alternative hypotheses

H1: branch growth is faster near the ground

H2: winter branch mortality is greater at higher up from drying

H3: branches break off from wind more frequently higher up



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From Bacon to Babies

Sir Frances Bacon (16th century) – [Hypothetico-deductive method](#)

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John Platt – (1964) [Strong inference](#)

Science in society [Who uses scientific thinking?](#)

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“Scientific reasoning does not differ from ordinary everyday thinking in kind, but merely in degree of refinement and accuracy, more or less as the performance of the microscope differs from that of the everyday eye.”

Max Planck

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“The scientist generally tries harder than the layman to screen out personal prejudice and check for possible error. He seeks to make his assumptions explicit and attends to the work of others in his field. He reports his findings more accurately and makes predictions that can in principle be tested precisely. **In all these respects he improves on the layman but does not eclipse him.**”

G.F. Kneller
A Method of Enquiry
[E-Res reading](#)

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“The real purpose of the scientific method is to make sure Nature hasn’t misled you into thinking you know something you actually don’t know.”

Robert Pirsig
Zen and the Art of Motorcycle Maintenance
[E-Res reading](#)

Science as a “Way of Knowing”

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Science in society

Science & Human Nature

The Scientific Method

Science & human nature

Science is usually characterized as

- Logically rigorous
- Repeatability by anyone
- Objective
- Unaffected by
 - Personal style / culture
 - Discipline involved
- Impersonal

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BUT... Scientists are Human

“One scientist is creative and original; another is systematic and predictable. Some work at the frontiers of their discipline. Others work at the edges or help fill in the blanks. Reliability and persistence are valued, but so are imagination and independence.”



J. Hatton

The Scientific Method

“Remarkably, students in the sciences are seldom asked to think about the nature of scientific knowledge and the ways by which science “knows”. And when they are, they are likely to think in terms of a prescribed and systematic method as though an understanding of nature follows automatically if only the appropriate procedures are followed.”

J. Hatton
Science and Its Ways of Knowing

The Scientific Method

“Such thinking cannot help but lead to a closed and essentially rigid view of science and its practitioners. The result is a limited and distorted notion regarding not only the nature of science but also its history and its grand achievements, to say nothing of the imagination and passion that so many of its practitioners have brought to it.”

J. Hatton
Science and Its Ways of Knowing

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Science & human nature

Scientists are Human

- Personality matters
- Disciplinary / Educational background matters
 - The double-edged sword of education:*
we see what we learn to see
- Cultural / Personal background matters

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Does the classical “scientific method” capture all of how science really works?

Building scientific understanding (the “Process of Science”) involves more than the classical scientific method.

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Does the classical “scientific method” capture all of how science really works?

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Discovery

- Classical scientific method

Validation

- Peer review & publication
- Presentation at meetings
- Tested / repeated by others (or same scientist)
- Reconciling results with accepted theoretical framework
- Standing the test of time

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**Beyond the classical “scientific method”:
The Process of Science**

Discovery

Science is practiced by individuals in some form of the scientific method

but

Validation

The impact of those individual contributions to scientific understanding are influenced by the community.

“If I have been able to see farther than others, it was because I stood on the shoulders of giants”

— Sir Isaac Newton 1642-1727



Science as a Way of Knowing

“**Science is a way of thinking** much more than it is a body of knowledge. Its goal is to find out how the world works... Our intuition is by no means an infallible guide.”

Carl Sagan

Science as a Way of Knowing

Science in Context

Is everything scientifically “knowable”?

“Not everything that can be counted counts, and not everything that counts can be counted.” — Albert Einstein

“Our formulations of the regularities of nature are surely dependent on how the brain is built, but also, and to a significant degree, on how the universe is built.” - Carl Sagan

- We understand nature through our **senses**
- Sensory perception provides **models of reality**, not reality itself
- **Models are abstractions** that provide a framework for prediction and understanding

Science as a Way of Knowing

Science in Context

Actions move beyond knowledge

“Wisdom is a combination of **knowledge**, which science can supply, and **moral understanding**, which science cannot. “

— Stephen Jay Gould