# Nature of scientific inquiry

# Scientific Method

What exactly is the “scientific method”?

A method of research in which:

- a **problem** is ***identified***
- **relevant data** are ***gathered***
- a **hypothesis** is ***formulated*** from these data
- and the **hypothesis** is ***empirically tested*** (by experimentation).

- Scientific method refers to a **standardized set of techniques** for building scientific knowledge.

- These include:

  -- how to make **valid observations**
  -- how to **interpret results**, and
  -- how to **generalize those results**

- The scientific method allows researchers to **independently** and **impartially** test **preexisting theories** and **prior findings**, and subject them to ***open debate***, ***modifications***, or ***enhancements***.

The **scientific method** must satisfy **four** characteristics:

1. **Replicability:**

Others should be able to **independently replicate** or **repeat** a scientific study and obtain **similar**, if not identical, results.

2. **Precision:**

**Theoretical concepts**, which are often hard to measure, must be **defined with such precision** that others can use those definitions to measure those concepts and test that theory.

## 3. Falsifiability:

A **theory** must be stated in a way that **it can be disproven**.

Theories that **cannot be tested or falsified are not scientific theories** and any such knowledge is **not scientific knowledge**.

A theory that is specified in **imprecise terms** or whose concepts are **not accurately measurable** cannot be tested, and is therefore **not scientific**.

**Sigmund Freud's ideas** on psychoanalysis fall into this category and is therefore not considered a "theory", even though psychoanalysis may have practical utility in treating certain types of ailments.

## 4. Parsimony:

When there are **multiple** explanations of a phenomenon, **scientists must always accept the simplest or logically most economical explanation.**

This concept is called **parsimony or "Occam's razor."**

Parsimony prevents scientists from pursuing **complex theories** with endless number of concepts and relationships that may explain a little bit of everything but nothing in particular.

- Any branch of inquiry that **does not allow the scientific method to test its basic laws or theories cannot be called "science."**

- For instance, **theology (the study of religion)** is **not science** because theological ideas (such as the presence of God) **cannot be tested by independent observers** using a **replicable, precise, falsifiable, and parsimonious method.**

- Similarly, **arts, music, literature, humanities, and law** are also **not considered science**, even though their importance cannot be denied.

- The scientific method, as applied to **social sciences**, includes a variety of research approaches, tools, and techniques, such as **qualitative** and **quantitative** data, **statistical analysis**, **experiments, field surveys, case research**, and so forth.

# SCIENTIFIC INQUIRY

- Scientific inquiry refers to the **diverse ways** in which scientists **study the natural world and propose explanations** based on the **evidence derived from their work**.

- Fundamentally, the various scientific disciplines are **alike** in their reliance on evidence, the use of hypothesis and theories, the kinds of logic used etc.

Nevertheless, **scientists differ greatly from one another** in what phenomena they investigate and in how they go about their work:

- in the reliance they place on **historical data** or on **experimental findings**
- and on **qualitative** or **quantitative** methods
- in their **reference to fundamental principles**
- and in how much they **draw on the findings of other sciences**

# Science Demands Evidence

- Sooner or later, the **validity of scientific claims** is settled by referring to **observations of phenomena**.
- Hence, scientists concentrate on **getting accurate data**.
- Such evidence is obtained by **observations and measurements** taken in situations that range from **natural** settings (such as a forest) to completely **artificial** ones (such as the laboratory).

- To make their observations, scientists use their **own senses**, **instruments (such as microscopes) that enhance those senses**, and **instruments that tap characteristics quite different from what humans can sense (such as magnetic fields).**

- Scientists observe **passively** (earthquakes, bird migrations), **make collections** (rocks, shells), and **actively probe the world** (as by boring into the earth's crust or administering experimental medicines).

- In some circumstances, scientists can **control conditions deliberately and precisely** to obtain their evidence.

- They may, for example, control the temperature, change the concentration of chemicals, or choose which organisms are useful.

- By varying **just one condition at a time**, they can hope to identify its exclusive effects on what happens, uncomplicated by changes in other conditions.

- Often, however, **control** of conditions may be **impractical** (as in studying stars), or **unethical** (as in studying people), or likely to **distort the natural phenomena** (as in studying wild animals in captivity).

- In such cases, observations have to be made over a **sufficiently wide range of naturally occurring conditions** to conclude what the influence of various factors might be.

- Because of this **reliance on evidence**, great value is placed on the development of **better instruments and techniques of observation**, and the findings of any one investigator or group are usually **checked by others**.

## Science Is a Blend of Logic and Imagination

- Scientists do not work only with data and well-developed theories.
- Often, they have only **tentative** (not certain) **hypotheses** about the way things may be.
- Such hypotheses are widely used in science for **choosing what data to pay attention to** and **what additional data to seek**, and for **guiding the interpretation of data**.

- In fact, the process of formulating and testing hypotheses is one of the **main activities** of scientists.

- To be useful, a hypothesis should suggest what evidence would **support it** and what evidence would be **against it**.

- A hypothesis that **cannot** in principle be put to the test of evidence may be interesting, but it is **not likely to be scientifically useful.**

- Sometimes discoveries in science are made **unexpectedly**, even by accident, e.g., penicillin.

- But knowledge and creative insight are usually required to **recognize the meaning of the unexpected**.

- Aspects of data that have been **ignored** by one scientist may lead to **new discoveries** by another.

## Science Explains and Predicts

- The **credibility** of scientific theories often comes from their ability to **show relationships** among phenomena that **previously seemed unrelated.**

- The theory of **moving continents**, for example, has grown in credibility as it has shown relationships among such diverse phenomena as earthquakes, volcanoes, the match between types of fossils on different continents, the shapes of continents, and the contours of the ocean floors.

## Scientists Try to Identify and Avoid Bias

- When faced with a **claim that something is true**, scientists respond by **asking what evidence supports it**.

- But scientific evidence can be **biased** in how the data are interpreted, in the recording or reporting of the data, or even in the choice of what data to consider in the first place.

- Scientists' nationality, sex, ethnic origin, age, political convictions, and so on may incline them to look for or emphasize **one or another kind** of evidence or interpretation.

- **Bias** attributable to the investigator, the sample, the method, or the instrument **may not be completely avoidable** in every instance, but scientists want to know the **possible sources of bias** and **how bias is likely to influence evidence.**

- Scientists want, and are expected, to be as alert to possible bias in their **own work** as in that of other scientists, although such objectivity is not always achieved.

- One safeguard against undetected bias in an area of study is to have many **different** investigators or **groups** of investigators working in it.

## Science Is Not Authoritarian

- It is appropriate in science, as elsewhere, to turn to **knowledgeable sources** of information and opinion, usually **people who specialize** in relevant disciplines.

- But **esteemed authorities** have been **wrong** many times in the history of science.

- In the long run, **no scientist**, however famous or highly placed, is **empowered to decide for other scientists** what is true, for none are believed by other scientists to have special access to the truth.

- There are no **pre-established conclusions** that scientists must reach on the basis of their investigations.

- In the **short run**, new ideas that do not combine well with mainstream ideas may encounter **vigorous criticism**, and scientists investigating such ideas may have difficulty obtaining support for their research.

- Indeed, **challenges to new ideas** are the legitimate business of science in building **valid knowledge**.


Thank You!