SC.203 - Scientific Method
Lecture 3 - Fundamental Blocks

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Acknowledgements

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  - Pr. Paul Burgess (2007) "*Nature and Practice of Science.*" Cranfield University, UK.

  - Pr. Vu Duong (2007) "*Scientific Research: Methods, Practices and Models.*" University of Technology & University of Science - Vietnam National University HCMC.

Key Building Blocks of Science (Gauch, 2003)

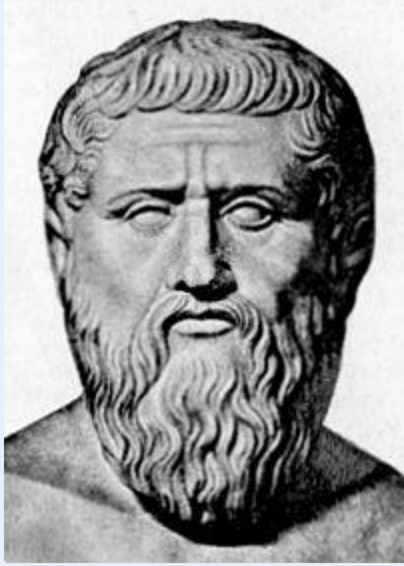
1. Presuppositions

Or Working Assumptions of Science...

- In Western educational system, Science seems an obvious way to learn about the world.
- (Recent) non-Western modes of thought show that behind the scientific approach lie certain assumptions about the world.
- Many scientists rarely think about these assumptions and take them for granted as part of western, scientific outlook.

- Reality of the World. **Realism** - the philosophy that objects perceived have an existence outside the mind.
- Rationality. A view that reasoning is the basis for solving problems.
- Regularity. A belief that phenomena exist in recurring patterns that conforms with universal laws.
- Discoverability. The belief that it is possible to learn solutions to question posed.
- Causality. **Determinism** - the doctrine that all events happen because of preceding causes.

2. Wonder?



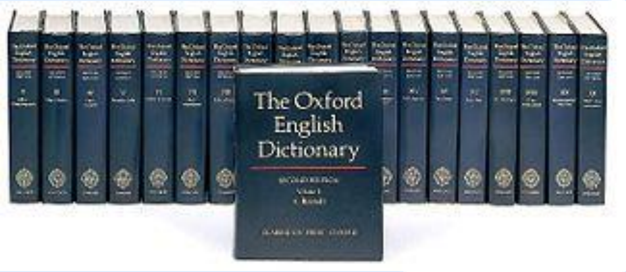
- "*Philosophy begins in wonder.*" Plato

- *"I suffice to wonder at these secrets and to attempt humbly to grasp with my mind a mere image of the lofty structure of all that there is."*

Einstein

- "*Wonder is an emotion of excitement by what is unexpected; a desire to know.*"

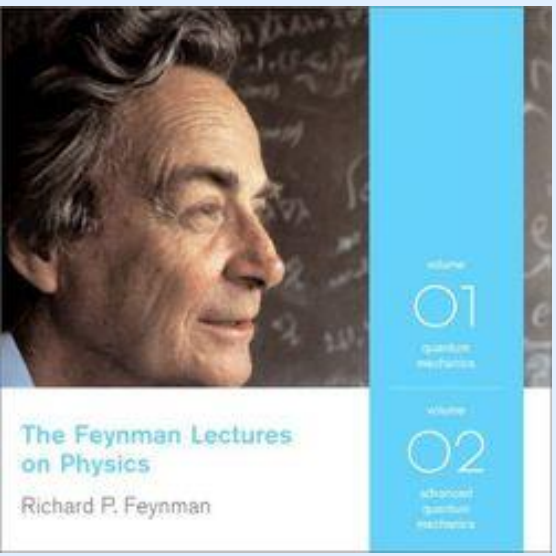
Oxford English Dictionary



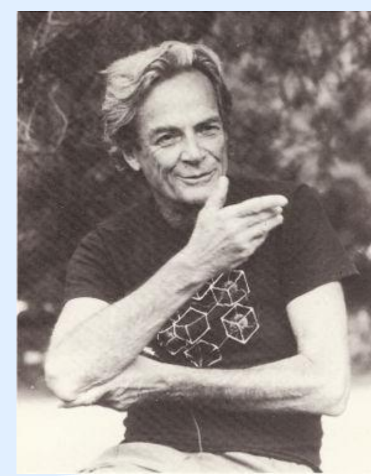
Wonder?

"It is in the admission of ignorance and uncertainty that there is a hope for the continuous motion of human beings in some direction."

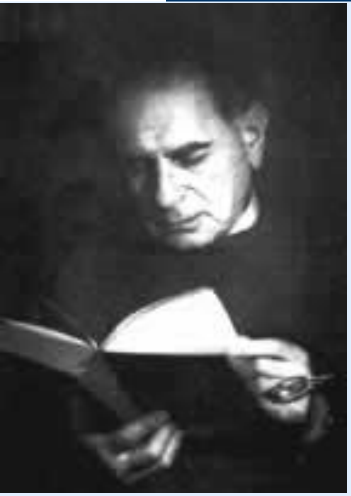
Richard Feynman (1963)



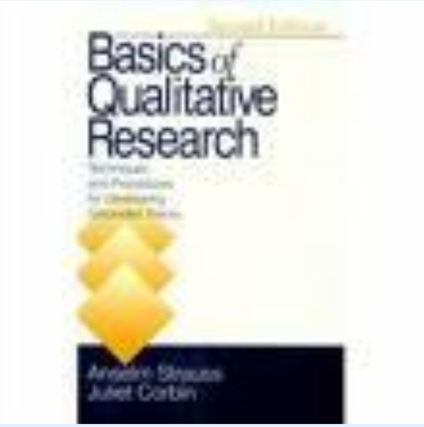
Richard Phillips Feynman (1918 –1988), American physicist known for expanding the theory of quantum electrodynamics, the physics of the **superfluidity** of supercooled liquid helium, and **particle theory**. For his work on quantum electrodynamics, Feynman was a joint recipient of the Nobel Prize in Physics in 1965, together with **Julian Schwinger** and **Sin-Itiro Tomonaga**; he developed a widely-used pictorial representation scheme for the mathematical expressions governing the behavior of subatomic particles, which later became known as ***Feynman diagrams***.



3. Theories



- A scientific theory is an universal statement (Popper, 1935)



A theory is: "a set of constructs, definitions and propositions that present a systematic view of phenomenon by specifying relations among variables"
(Kerlinger, 1973)

- The purpose of a theory is to describe, explain and predict

(Borgatta & Montgomery, 2000)

Hypothesis

- A supposition made as a starting point for further investigation.
- If a hypothesis survives repeated testing, it could become a theory.

Hypothesis

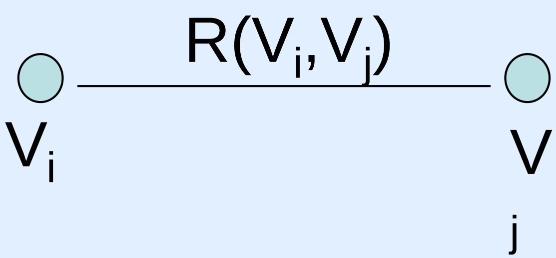
- Hypothesis expresses the elements of a research problem.
- Therefore, the hypotheses define the set of experiments to be conducted during the research.
- In practice, a research topic contains more than one unknown. During the scientific or technologic research process, the researcher drives for the clarification of this unknown with irrefutable evidences or proofs.
- It is important that these hypotheses be well-posed.

Forms of Hypotheses (1)

- Declarative
  - Expresses the relations between variables that investigators expect to converge.
  - e.g., «*There's significant increase in the consumption of a car using multi-viscosity oil comparing with those using mono-viscosity oil.* »

Forms of Hypotheses (2)

- **Negative (null or falsified):**
  - **Expresses the <u>nonexistence</u> of relations between experimental variables.**
  - **Doesn't necessarily represent what the experimenter expected but often used due to natural fitting with statistical techniques many of which aim at measuring the unlikelihood (that a found difference be higher than zero).**



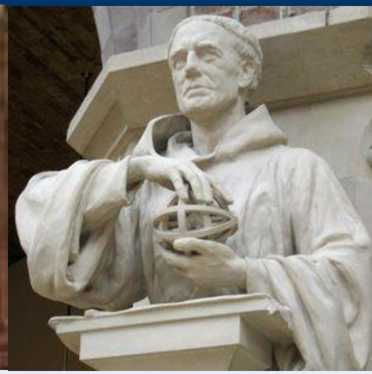
$$\forall(V_i,V_j) : R(V_i,V_j) \perp \varnothing$$
$$\Leftrightarrow P_{R(vi,\ vj)} \approx 0$$

- Attention to confusion because expression is contrary to expectation.
- Example: «*The increase in the consumption of a car using multi-viscosity oil is not significant comparing to those using mono-viscosity oil.* »

Forms of Hypotheses (3)

- Interrogative:
  - Under the form of questions, the hypothesis interrogates about the the possible possible between experimental variables.
  - More natural for beginners,
  - Example : «Is there any significant increase in the consumption .... ? »

4. Data



Robert Grosseteste (1168-1253) and Roger Bacon (1214-1294) considered that data should have priority over theories.

Scientific explanation involves the accurate and precise measurement of phenomena (Borgatta & Montgomery, 2000)

5. Logic: Induction

On the basis of the data, a theory is developed

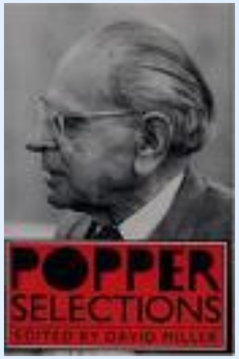
Inferred Theory

Actual data

Starts with observations

-A sleeps in class,
-B sleeps in class,
-C sleeps in class,
Therefore:
All people sleeps in class!

Induction:
-from the samples to the population,
-from particular statements to universal statements



Induction or **inductive reasoning**, sometimes called **inductive logic**, is the process of reasoning in which the premises of an argument are believed to support the conclusion but do not ensure it. It is used to ascribe properties or relations to types based on tokens (i.e., on one or a small number of observations or experiences); or to formulate laws based on limited observations of recurring phenomenal patterns. Induction is employed, for example, in using specific propositions such as:
This ice is cold.
A billiard ball moves when struck with a cue.
...to infer general propositions such as:
All ice is cold.
All billiard balls struck with a cue move.
Inductive reasoning has been attacked several times. Historically, **David Hume** denied its logical admissibility. During the twentieth century, thinkers such as **Karl Popper** and **David Miller** have disputed the existence, necessity and validity of any inductive reasoning, including probabilistic (Bayesian) reasoning © wikipedia.

Test for good inductive arguments

1. The number of observations forming the basis of the generalisation must be large

How many is large?

2. The observations must be repeated under a wide variety of conditions

What is a significant variation in condition?

3. No accepted observation should conflict with the derived law

How do we know that there are no exceptions?

Chalmers (2002) page 46

5. Logic: Deduction

Starts with a theory or premises

Given theory

↓

Expected data

which lead to an expected result

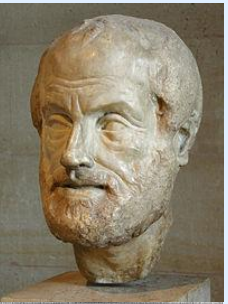
In the physical sciences, deductive reason tends to be deterministic; i.e. X determines Y

In the biological and social sciences, deductive reason tends to be probabilistic; i.e. X probably determines Y

General law

premise

-All people sleeps in class, *and*
-This is a person, *therefore*
-This person sleeps in class

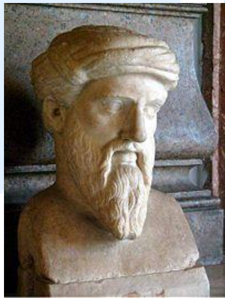


Deduction:
-from general law to particular instances thru inference,
-The truth of all its premises validates the conclusion.

Deductive reasoning was developed by **Aristotle**, **Thales**, **Pythagoras**, and other **Greek philosophers** of the Classical Period (600 to 300 B.C.). Aristotle, for example, relates a story of how Thales used his skills to deduce that the next season's olive crop would be a very large one. He therefore bought all the olive presses and made a fortune when the bumper olive crop did indeed arrive.
Deductive reasoning is dependent on its premises. That is, a false premise can possibly lead to a false result, and inconclusive premises will also yield an inconclusive conclusion.

All apples are fruit.
All fruits grow on trees.
Therefore all apples grow on trees.

Or
All apples are fruit.
Some apples are red.
Therefore some fruit is red.



Criticism of Deduction

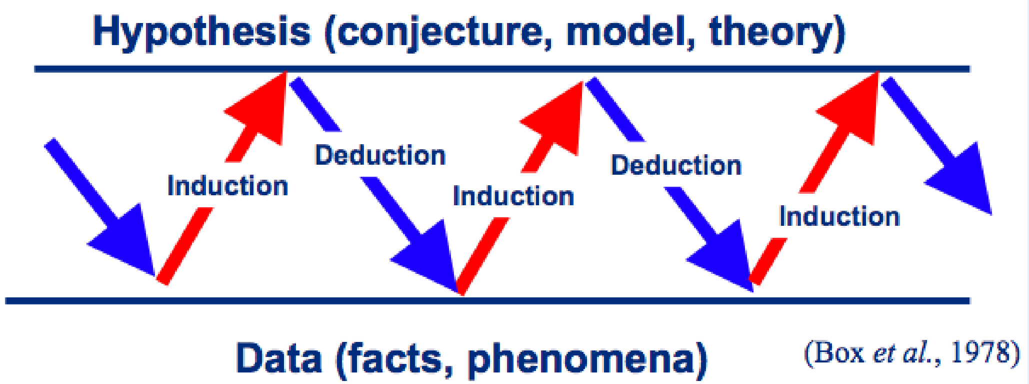
- The validity of the argument does not guarantee the truth of the conclusion, the premises may be false.
- Deduction can never allow us to say anything new or informative about the world because the conclusion is already contained in the premises.

Burgess, 2007

Induction vs. Deduction

- Induction involves gathering together a collection of data - observations, experimental results, etc - and formulating a generalization which reasonably explains them all.
- Deduction begins with a generalization. Predictions are made on the generalization, and those predictions are challenged. This, in essence, the testing part of science.

- Scientific Method involves both induction and deduction. Most scientific investigations, whether they follow a scientific method's protocol or not, reiterate between induction and deduction.



"Science is a process that progressively explores …by means of a systematic alternation between induction and deduction" (Rubenstein *et al.*, 1984)

Scientific Method

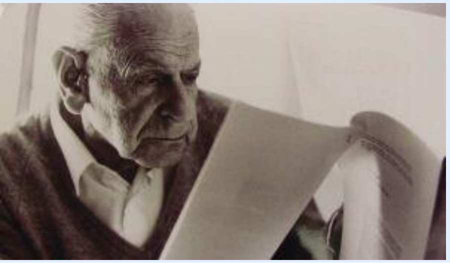
“ ***Scientific explanation uses empirical observation, theories, and inductive and deductivelogic to determine what is true and what is false.”***

(Borgatta and Montgomery, 2000)

6. Testing: Falsifiability

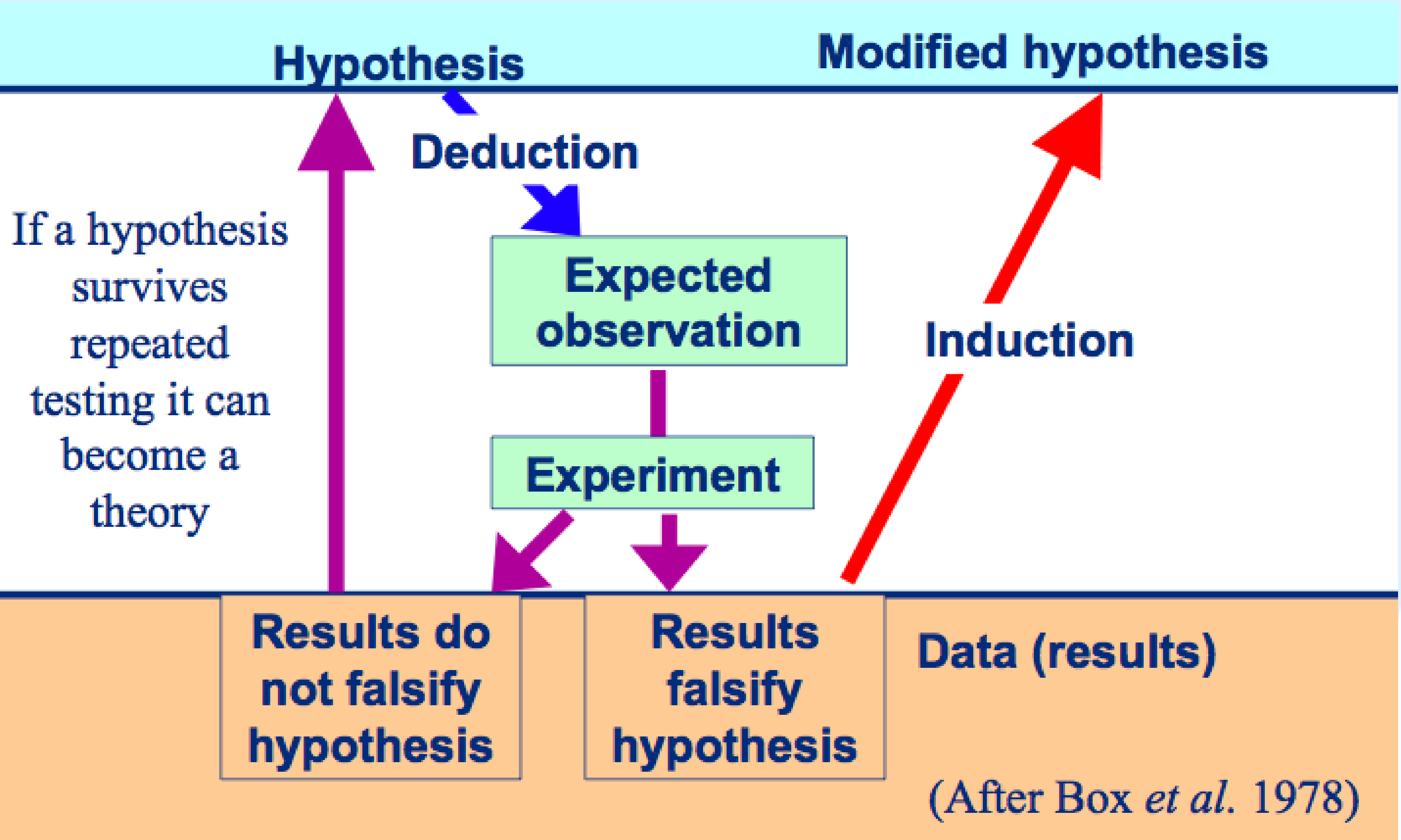
- **Grosseteste (1168-1253) developed a method for falsification (Gauch, 2003)**
- **"*Falsifiability is what distinguishes science from non- science*" "*One can never absolutely confirm theories, one can definitely falsify them*" Karl Popper (1902-1994)**
- **The aim of science is to falsify theories and to replace them with better theories (Chalmers, 2002)**
- **All scientific statements are subject to empirical falsification (Borgatta & Montgomery, 2000)**

"I wished to distinguish between science and pseudo-science; knowing very well that science often errs, and that pseudo-science may happen to stumble on the truth.
...
Thus the problem which I tried to solve by proposing the criterion of falsifiability was neither a problem of meaningfulness or significance,
nor a problem of truth or acceptability.
It was the problem of drawing a line (as well as this can be done)
between the statements, or systems of statements, and all other statements."



Sir Karl R. Popper
in Conjectures and Refutations: The Growth of Scientific Knowledge
Routledge and Kegan Paul, Pub. London, 1963, pp.33-39
Reprinted in Readings in the Philosophy of Science, From Positivism to Postmodernism
Theodore Schick Jr. (editor), Mayfield Publishing, California , 2000, pp.9-13

Hypothesis Testing



Summary

"A scientific method or process is considered fundamental to the scientific investigation and acquisition of new knowledge based upon **physical evidence**.

Scientists use ***observation***, ***hypotheses*** and ***deductions*** to propose ***explanations*** for natural phenomena in the form of *theories*.

Predictions from these theories are tested by **experiment**. If a prediction turns out to be correct, the theory survives. Any theory which is cogent enough to make predictions can then be tested reproducibly in this way.

The method is commonly taken as the ***underlying logic of scientific practice***.

A scientific method is essentially an extremely cautious means of building a supportable, evidence-based understanding of our natural world."