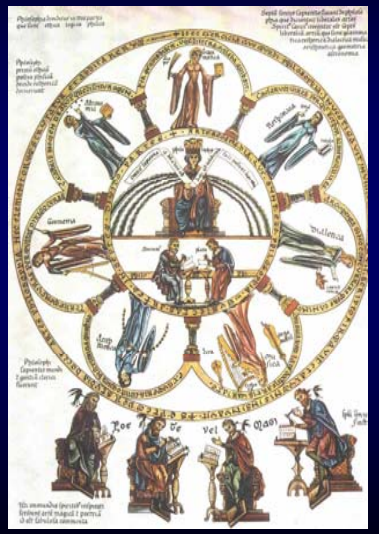
What is 'science'?

science < *scientia* < *sciens* < *scio, scire*

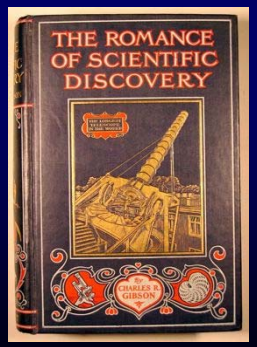
The state or fact of knowing; knowledge or cognizance of something specified or implied; also, with wider reference, knowledge (more or less extensive) as a personal attribute. Now only Theol. … and occas. Philos. in the sense of 'knowledge' as opposed to 'belief' or 'opinion' (OED)

- Distinction of science (= *epistéme*), concerned with theoretic truth *or* dependent on knowledge and conscious application of principles, and art (= *téchne*), concerned with practical methods *or* knowledge of traditional rules and skill acquired by habit.
- Branch of knowledge: 'the seven liberal sciences' = 'the seven liberal arts'; *Trivium* (grammar, logic, rhetoric) and *Quadrivium* (arithmetic, geometry, music, astronomy).
- late 19th century: 'natural and physical science'



Inflationary use of "science"

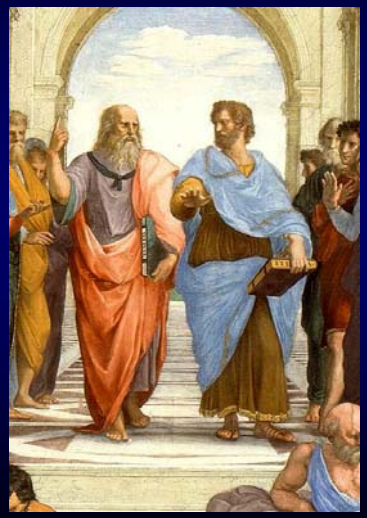
- "scientifically tested", "clinically proven"
- unbridled optimism of scientific progress: early 19th century until 1945
- challenge to superiority of science



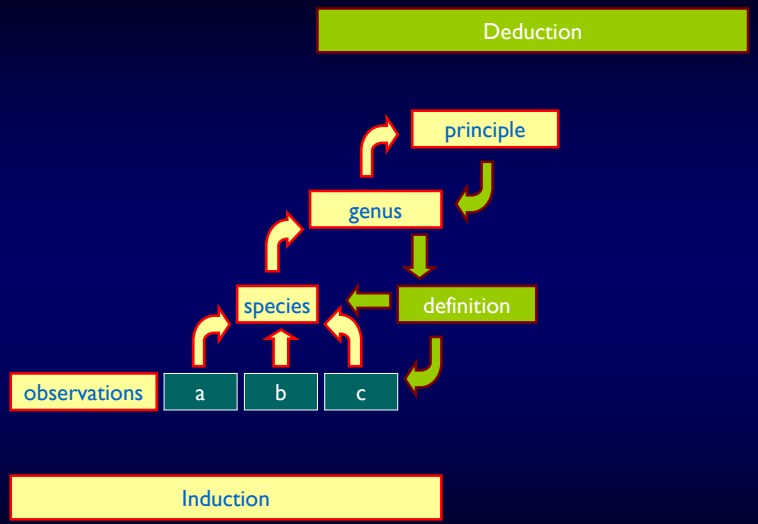
scientific method: a method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses (OED)

Aristotle (384-324 BC)

- logic, metaphysics, ethics, poetics, 'science'
- role of science: derive the existent from a cause (*aitía; cf. aetiology*)
- 1. induction: from particular to general
  - enumerative v. intuitive
  - generalization: recognition of shared qualities > statements of explanatory principles

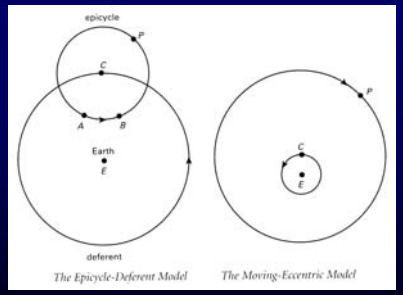


- 2. deduction: from general to particular
  - syllogism
    - All *M* are *P*
    - All *S* are *M*
    - ∴ All *S* are *P*
  - indemonstrability of premises (necessary truth): *scientific laws*
  - causal relatedness
- teleological explanation: cause



After Aristotle

Mathematical models: regularity in nature
- Pythagoras
- Ptolemy



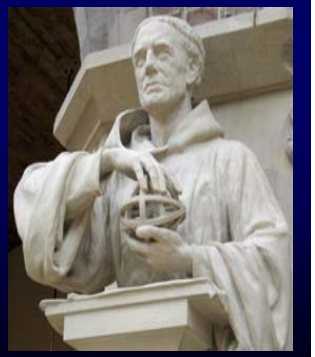
Losee, 1972

Dichotomy of art and science
- superiority of reason
- limitations of technique
- exception: medicine

> Long term stagnation

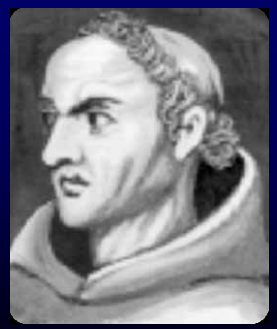
Medieval approaches to enquiry

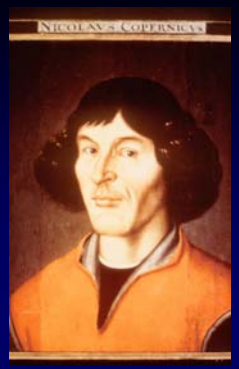
- Unity of philosophy, natural research and theology achievable through rational examination
- Roger Bacon (1290-1292; *Doctor Mirabilis*)
  - four sources of error:
    - false authority
    - habit
    - prejudice
    - apparent but false knowledge
  - *scientia experimentalis*
    - verification by direct experience of conclusions deduced from principles
    - produce truths not discoverable by other sciences
    - investigate the secrets of nature, allowing a knowledge of past and future



William of Ockham (c.1280-c.1348)

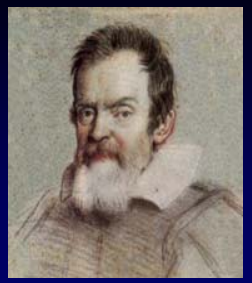
- "Ockham's razor": elimination of superfluous concepts (*pluralitas non est podenda sine necessitate*)
- scepticism
- omnipotence principle





The "new science"

- Nicolaus Copernicus (1473-1543)
  - 1543 *De revolutionibus orbium coelestium*
  - mathematical harmony
  - [Vesalius (1514-1564): 1543 *De humani corporis fabrica*]
- Johannes Kepler (1571-1630)
  - quantitative aspects of science supplants metaphysical aspects



Galileo Galilei (1664-1642)

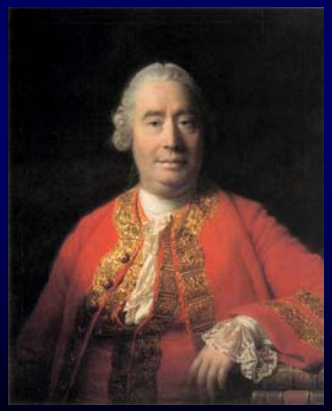
- analysis; hypothesis; experiment; deduction; mathematical laws of nature
- role of abstraction in science
- explanation of discrepancies

Isaac Newton (1643-1727)

- "experimental philosophy"
- role of abstraction and intuitive leaps
- contingency of natural laws: role of revision
  - *hypotheses non fingo*
- rules for reasoning: exclude the unnecessary, assign the same cause to the same effects, retain a proposition until experience demonstrates its falsity

Hume and the problem of causality

- *Empiricism* and *scepticism*
  - John Locke (1632-1704)
  - George Berkeley (1686-1753)
- David Hume (1711-1776)
  - 1739/40 *Treatise on Human Nature*
  - law of association: cause and effect
  - BUT: necessity a property of the mind, not of objects
- *Can anything be demonstrated by induction?*



Meanwhile …

Nature, and Nature's laws lay hid in night:
God said, *Let Newton be!* and all was light.

Alexander Pope (1688-1744)

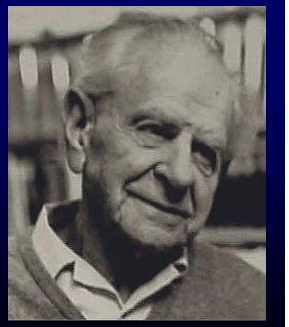
1729 Electric current discovered
1747 Franklin's theory of electricity
1762 Linnaeus' classification of plants and animals
1781 Watt's steam engine
1799 Volta's battery
1808 Dalton's atomic theory
1817 Young's wave theory of light
1828 Urea synthesized
1849 Darwin's theory of evolution

... etc. etc. etc.!

Karl Popper (1902-1994) and *falsifiability*

- essentialism v. nominalism (cf. logical positivism)
- inductive conclusions are not compelling
- theories as hypotheses which tend to the truth
  - number, diversity and severity of tests decisive
  - all experience determined by theory
- permission to neglect 'extreme improbabilities'

- Freud, Marx
- BUT: for instance, cosmological theories, evolution



Thomas Kuhn (1922-1996) and scientific progress

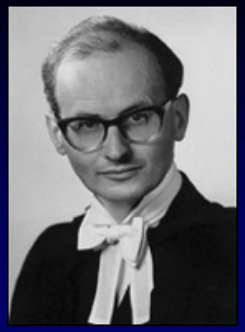
- models as imaginary worlds
- *The Structure of Scientific Revolutions* (1962)
  - critical of view of science as continuous increase of knowledge through better data and more inclusive theories; cf. relativity
- three phases of scientific research:
  - pre-scientific: no consensus
  - normal: accepted paradigm determines acceptable questions, methods, interpretations
  - revolution: initiated by anomalies leading to crisis in normal phase
- examples: Copernicus, Einstein

Incommensurability

- *The competition between paradigms is not the kind of battle that can be resolved by proof* (Kuhn)
- Differences in definition of terms and of problems, of views regarding appropriate approaches to problems, of validity of proofs: incompatible worldviews
- Does science have any special access to truth?
- Is scientific progress possible?

A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it (Max Planck, 1858-1947)

Imre Lakatos (1922-1974)



- Kuhn as 'irrationalist'
- 'research programs': core propositions and auxiliary hypotheses

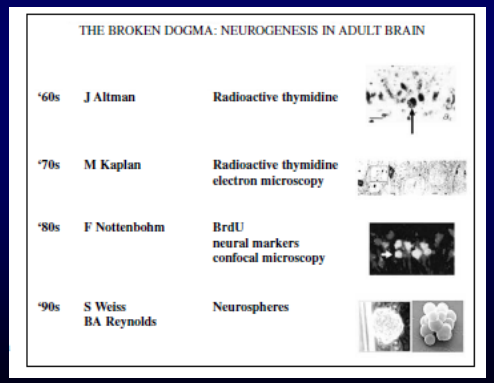
- no single test falsifies a program: *It is not that we propose a theory and Nature may shout NO rather we propose a maze of theories and nature may shout INCONSISTENT.*
  - progressive and degenerative problem shifts

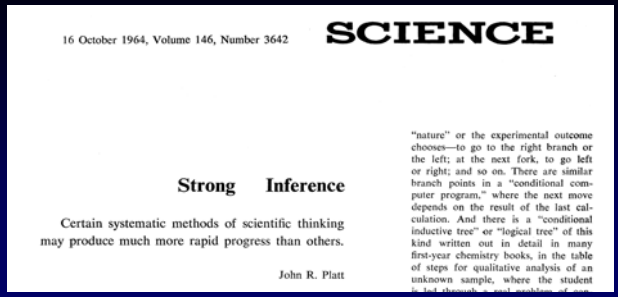
Neurol Sci (2006) 27:266–270
DOI 10.1007/s10072-006-0682-z

HISTORY OF NEUROLOGY

L. Colucci-D'Amato • V. Bonavita • U. di Porzio

The end of the central dogma of neurobiology: stem cells and neurogenesis in adult CNS




16 October 1964, Volume 146, Number 3642
SCIENCE

Strong Inference

Certain systematic methods of scientific thinking may produce much more rapid progress than others.

John R. Platt

"nature" or the experimental outcome chooses—to go to the right branch or the left; at the next fork, to go left or right; and so on. There are similar branch points in a "conditional computer program," where the next move depends on the result of the last calculation. And there is a "conditional inductive tree" or "logical tree" of this kind written out in detail in many first-year chemistry books, in the table of steps for qualitative analysis of an unknown sample, where the student

1) Devise alternative hypotheses;
2) Devise a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses;
3) Carry out the experiment so as to get a clean result;
1') Repeat, making subhypotheses or sequential hypotheses to refine the possibilities that remain; and so on.

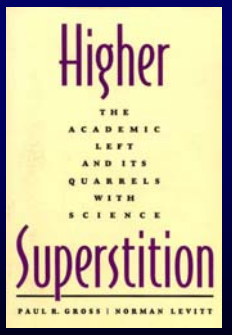
see also: Davis, Rowland H. (2006) Strong Inference: rationale or inspiration? *Perspectives in Biology and Medicine* 49: 238-249.

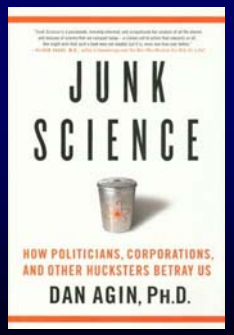
"But what is so novel about this? " someone will say. This is *the* method of science and always has been, why give it a special name? The reason is that many of us have almost forgotten it. Science is now an everyday business. Equipment, calculations, lectures become ends in themselves. How many of us write down our alternatives and crucial experiments every day, focusing on the *exclusion* of a hypothesis? We may write our scientific papers so that it looks as if we had steps 1, 2, and 3 in mind all along. But in between, we do busywork. We become "method-oriented" rather than "problem-oriented." We say we prefer to "feel our way" toward generalizations. We fail to teach our students how to sharpen up their inductive inferences. And we do not realize the added power that the regular and explicit use of alternative hypothesis and sharp exclusion could give us at every step of our research.

The difference between the average scientist's informal methods and the methods of the strong-inference users is somewhat like the difference between a gasoline engine that fires occasionally and one that fires in steady sequence. If our motorboat engines were as erratic as our deliberate intellectual efforts, most of us would not get home for supper.

The importance of being able to identify *science*

- Freud, homeopathy, racial theories
- evolution
- opponents of science





http://skepdic.com/tijunk.html
http://www.quackwatch.org

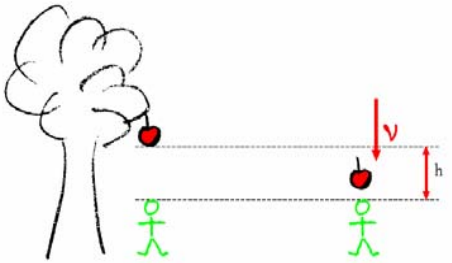
Critics of the validity of science

- Fallibility of science
  - BSE
  - thalidomide
  - dietary advice
  - climate change
- Reasonable v. proved
- Scientific statements as probabilistic
  - value lies in their level of substantiation, not any claim to absolute truth

What then is science?

- scientists accept the objective reality of world, and believe that it can be meaningfully known
- *manifestare ea quae sunt sicut sunt*: to show things as they really are (Friedrich II Hohenstaufen)

World 1: The real world	World 2: The experienced world (thinking & feeling)	World 3: The explained world



Laws of motion (Galileo, 1602)

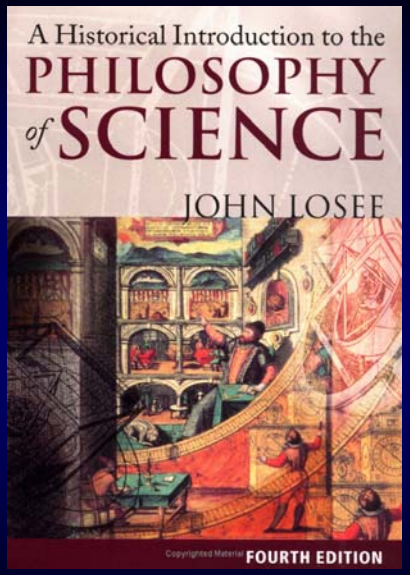
no air resistance:

$$v = \sqrt{2gh}$$

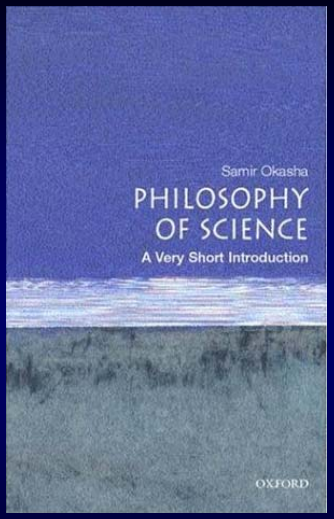
with air resistance:

$$v = \sqrt{\frac{mg}{a}}\sqrt{1 - e^{-\frac{2ha}{m}}}$$

- no single scientific method
- evolved consensus regarding objects, methods and standards of testing
- striving to achieve universally valid results
- recognition of contingency, but resistant to unnecessary sudden abandonment of prevailing orthodoxy
- BUT: no claim to finality or infallibility
- philosophy, methods and results evolve and fertilize each other
- internally consistent
- anomalies recognized and not simply dismissed
- boundaries of science



$30 or UNSW library



$20 or Sydney University library