A brief history of philosophy of science

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A brief (and grossly incomplete) history of philosophy of science

Ancient Greece and Aristotle (384-322 BCE)

- first elements of inductive scientific methodology in Greek Antiquity
- Aristotle believed that to know a thing's nature is to know the reason why it is and that we possess scientific knowledge of a thing only when we know its cause
- idea of generalization from particular observation to universal law of nature, and back from universal law to particular prediction
- continuity of philosophical and 'scientific' work

Aristotle's theory of causality

According to Aristotle, the cause of something (e.g. a statue) consists in four kinds of causes:

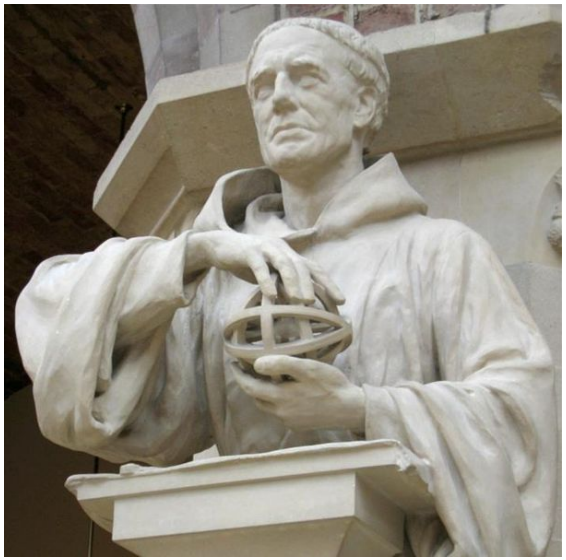
1. material cause: the matter which constitutes the thing (the substance or material of the statue)
2. formal cause: the essence or form of that thing (the shape of the statue)
3. efficient cause: the agency producing the result (the sculptor)
4. final cause: the purpose or sake of which the result is produced, i.e., the end towards which it is produced (the purpose of the staute)

- But: it seems as if there are events, which are clearly caused, but do not fit Aristotle's theory (such as a lightning flash)

Robert Grosseteste (1175-1253), Bishop of Lincoln

- "the real founder of the tradition of scientific thought in mediæval Oxford" (A C Crombie)
- first to fully grasp Aristotelian methodology in West
- explained generalization from observation to law and back to prediction via notions of 'resolution' and 'composition'
- principles governing both paths must be verified by observation and experimentation

Roger Bacon (c. 1214-1294), 'Doctor mirabilis'



- delivered philosophical justification for experimentation and observation (rather than reliance on authority) as the source of true knowledge in scientific and theological matters
- premises of experimental sciences require verification by sciences more perfect than themselves, i.e. by mathematics

Roger Bacon, *Opus majus*, II, Part IV 'On Mathematical Science', 1268:

> *If in other sciences we should arrive at certainty without doubt and truth without error, it behooves us to place the foundations of knowledge in mathematics.*

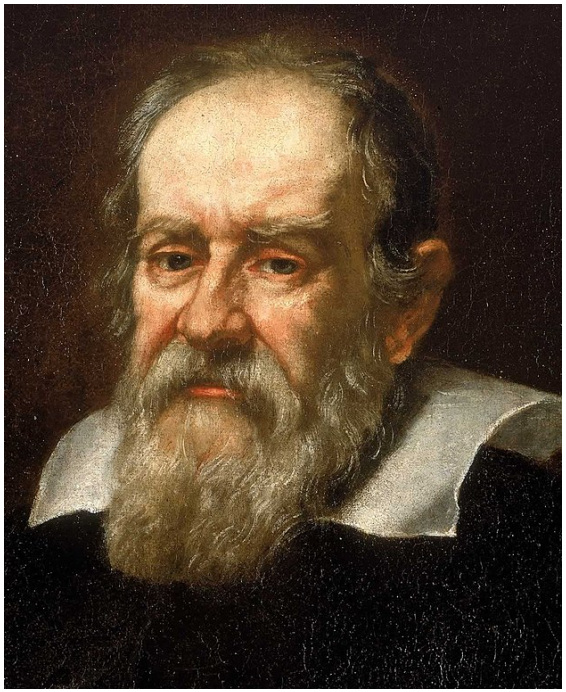
Roger Bacon, *Opus majus*, II, Part VI 'On Experimental Science', 1268:

> *There are two ways of acquiring knowledge, one through reason, the other by experiment. Argument reaches a conclusion and compels us to admit it, but it neither makes us certain nor so annihilates doubt that the mind rests calm in the intuition of truth, unless it finds this certitude by way of experience. Thus many have arguments toward attainable facts, but because they have not experienced them, they overlook them and neither avoid a harmful nor follow a beneficial course. Even if a man that has never seen fire, proves by good reasoning that fire burns, and devours and destroys things, nevertheless the mind of one hearing his arguments would never be convinced, nor would he avoid fire until he puts his hand or some combustible thing into it in order to prove by experiment what the argument taught. But after the fact of combustion is experienced, the mind is satisfied and lies calm in the certainty of truth. Hence argument is not enough, but experience is.*

Sir Francis Bacon (1561-1626), 1st Viscount St Alban

- systematic establishment and popularization of inductive methodology
- *Novum Organum*, 1620
- argued that reasoning from fact to axiom to law must be inductive, rather than deductive (as was the case in the Aristotelian tradition)
- induction alone is insufficient, negative instances must be carefully examined (early principle of falsification)
- reproducibility of scientific findings
- natural laws, not mysterious substances or final causes, have explanatory power
- human (and therefore scientific) knowledge is cumulative; as contrasted by given a priori (in Scripture or Aristotelian texts)

Galileo Galilei (1564-1642)



- concerned with the quantification of experimental results
- introduced time as a physical parameter to measure motion quantitatively
- insisted on the mathematical nature of laws of nature

Galileo Galilei, *Il Saggiatore* (The Assayer), 1623:

> *Philosophy is written in this grand book—I mean the universe—which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering about in a dark labyrinth.*

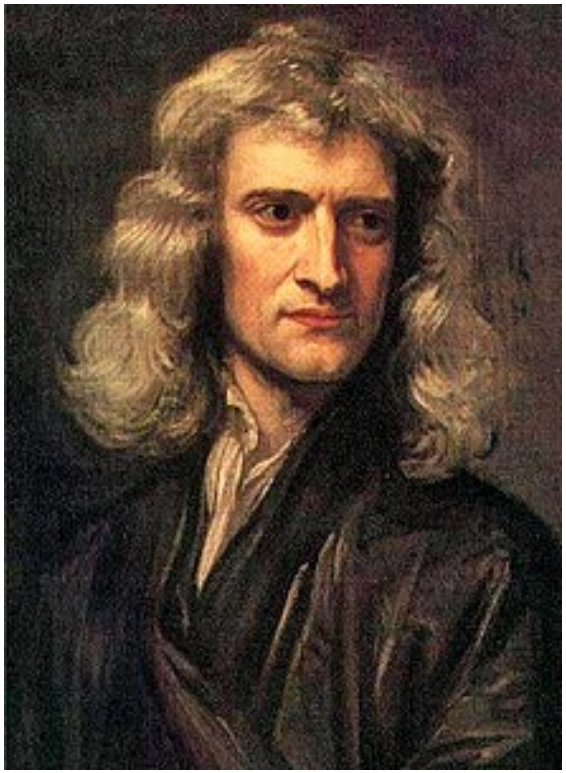
René Descartes (1596-1650)

Discours de la méthode (1637): method of philosophical thinking is exhausted by four precepts (II.7-10):

1. never accept anything for true which cannot be recognized clearly and distinctly so as to exclude all grounds of doubt
2. divide each of the difficulties under examination into as many parts as necessary
3. begin with objects the easiest to know, ascend by little and little to the more complex
4. always examine whether completeness and full generality has been achieved

Meditationes de prima philosophia (1641): systematic doubts concerning reliability of senses, certainty in "cogito, ergo sum"

Sir Isaac Newton (1643-1727)



- issue of the proper role of 'hypotheses' in systematic enquiries into nature (also in Descartes and Leibniz)
- "hypotheses non fingo" (I feign no hypotheses, *Principia*, 1687)
- impropriety of introduction of 'metaphysical' hypothesis in science (against Descartes and Leibniz)
- but: needs hypotheses himself...

Isaac Newton, Letter to Robert Hooke, 1676, and almost verbatim in *Principia*:

> *I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypotheses; for whatever is not deduced from the phenomena is to be called a hypothesis, and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy.*

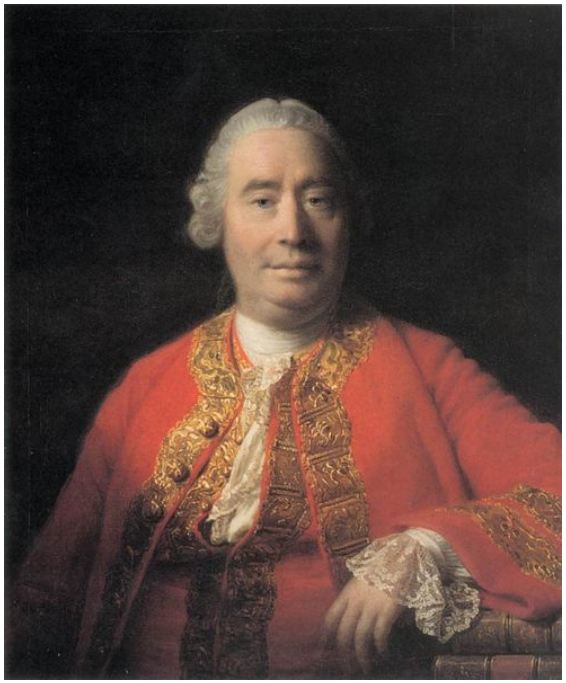
Gabrielle Émilie Le Tonnelier de Breteuil (1706-1749), marquise du Châtelet

- Her translation and interpretation of Newton was authoritative, and her comprehensive philosophical vision based on Newtonian physics influenced a generation of philosophers: Voltaire, d'Alembert, Kant.
- important criticism of Locke and Descartes: mathematics is an instrument for identifying essential connections in nature, but it is not identical to the facts it describes, and therefore never the primary source of knowledge
- prescient insight: "One experiment is not enough to admit a hypothesis, but one is enough to reject it when it is contrary to it." (*Institutions de physique*, §64)

«Emilia Newtonmania»

- frontispice of the popularisation of Newtonian physics by Voltaire, entitled *Éléments de la philosophie de Newton*: Châtelet directs the light coming from Newton to Voltaire

David Hume (1711-1776)



- one of most outspoken and sublest defender of empiricism (combined with scepticism and naturalism)
- problem of induction: the reliability of an inductive inference from past experience to prediction concerning future must be underwritten by a principle of induction
- but such a principle cannot claim logical necessity; nor can it be based on the past success of induction on pain of circularity
- nevertheless: induction is necessary tool for empirical sciences

David Hume, *An Enquiry Concerning Human Understanding*, Book V, Part I, 1748:

> *Custom... is the great guide of human life. It is that principle alone which renders our experience useful to us, and makes us expect, for the future, a similar train of events with those which have appeared in the past. Without the influence of custom, we should be entirely ignorant of every matter of fact beyond what is immediately present to the memory and senses. We should never know how to adjust means to ends, or to employ our natural powers in the production of any effect. There would be an end at once of all action, as well as of the chief part of speculation.*

Immanuel Kant (1724-1804)

- rational human agent at center of cognitive activity
- synthesis of rationalist and empiricist positions
- rational order of world cannot simply be accounted for by sense perceptions
- conceptual unification and integration by active mind using ‘precepts’ (space, time) and following ‘categories of understanding’ (cause, substance) operating on manifold of sense perceptions
- consequently, objective causal structure of world depend upon mind
- mind makes ineliminable constitutive contribution to knowledge

Immanuel Kant, *Critique of Pure Reason*, 1781/87:

> *There can be no doubt that all our knowledge begins with experience. (B 1)... Thoughts without content are empty, intuitions without concepts are blind. (B 75) [Sometimes paraphrased as 'Concepts without percepts are empty, percepts without concepts are blind.']... Thus all human knowledge begins with intuitions, proceeds from thence to concepts, and ends with ideas. (B 730)*

Bernard Bolzano (1781-1848)

- *Theory of Science* (1837)
- attempted to provide logical foundations of science, building on abstractions like part-relation, abstract objects, attributes, sentence-shapes, ideas-as-such, propositions, sums and sets, and sentence-occurrences
- these abstractions exist independently of our minds
- logical consequence is not identical with explanation

Auguste Comte (1798-1857), positivism

- *Cours de philosophie positive* (1830-1842)
- only scientific knowledge is authentic knowledge
- strict application of scientific method, completely barring any metaphysics (and any theology)
- circular dependence of theory and observation
- knowledge possible of facts, rather than of causes
- founder of sociology: applied scientific methods to social world

William Whewell (1794-1866)

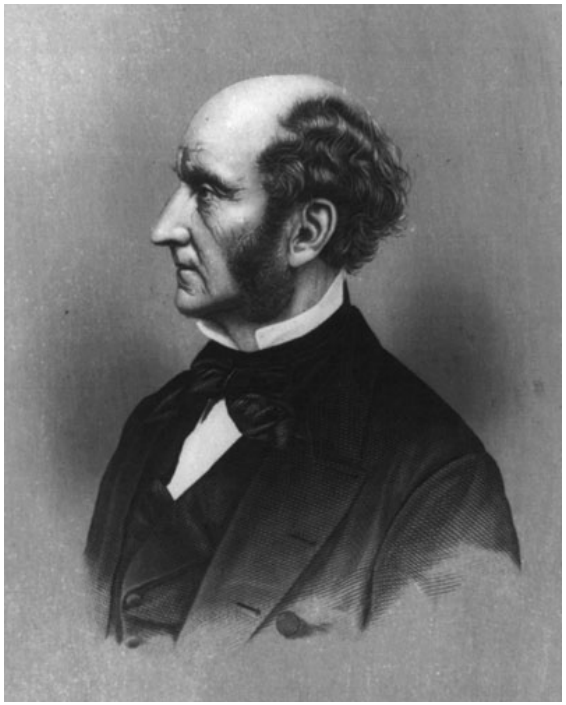
- *The Philosophy of the Inductive Sciences, Founded Upon Their History* (1840/47)
- knowledge involves both ideal and empirical elements, 'fundamental ideas' (space, time, cause) necessary
- i.e. observation is 'idea-laden', involves 'unconscious inference'
- 'renovated' F. Bacon's notion of induction
- induction more than enumeration and extending to unobserved instances
- generalization in induction requires element of 'colligation', i.e. the mental act of bringing together empirical facts in way that renders them capable of being expressed by a general law (pearls and string)

Whewell: *Novum Organon Renovatum* (1858)

Confirmation of hypothesis discovered via induction occurs by:

1. prediction: "our hypotheses ought to fortel [sic] phenomena which have not yet been observed" (p. 86)
2. consilience: "explain and determine cases of a kind different from those which were contemplated in the formation" of those hypotheses (p. 88)
3. coherence: hypotheses must "become more coherent" over time (p. 91)

John Stuart Mill (1806-1873)



- *A System of Logic* (1843)
- Mill's notion of induction does not involve mental acts such as 'colligation'
- five principles of induction: the method of agreement, the method of difference, the joint or double method of agreement and difference, the method of residues, and the method of concomitant variations
- to explain a fact is to locate a law under which it can be subsumed: covering-law model of explanation

Mill on the method of difference

John Stuart Mill, *A System of Logic* (1843) Book III, Ch. viii, §2:

> *If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former: the circumstance in which alone the two instances differ, is the effect, or cause, or a necessary part of the cause, of the phenomenon.*

Ernst Mach (1838-1916)

- methodological economy of thought: scientific laws are mere summaries of experimental events, constructed for the purpose of human comprehension
- thus, laws are essentially mental constructions
- empiricism: knowledge of the natural world must be grounded in experience (directly via sense impressions or via measurement results)
- uncompromising reductionism
- discussions on the reality of scientific theories are completely superfluous, only their utility counts

Positivism according to Mach

1. The source of human knowledge is the 'given'.
2. Only a manifold of sense impressions is given.
3. Whatever constitutes the 'world' over and above the contents of sense preceptions is not given.
4. The distinction between the I and the world is untenable.
5. There is no metaphysical knowledge about an extra-perceptual reality.

Charles Peirce (1839-1914)

- sign-theoretic or semiotic theory of inference
- examined three fundmental modes of inference: abduction, deduction and induction
- abduction ($\approx$ inference to the best explanation), is used to generate a likely hypothesis in response to phenomenon under scrutiny
- pragmatic considerations, i.e. considerations on the practical consequences, significantly enter the abductive work

Henri Poincaré (1854-1912), conventionalism

- *La science et l'hypothèse* (1902), *Science et méthode* (1908)
- conventionalism: laws and theorems relevantly rest upon conventions
- geometry of physical space is conventional: either one stipulates properties of measuring devices and determines the geometry of space, or one stipulates a geometry of space and infers geometrical properties of physical bodies such as measuring devices
- but conventions are not arbitrary, they are constrained e.g. by rules which must be followed in negotiating them

Pierre Duhem (1861-1916), holism

- *La théorie physique son objet et sa structure* (1906)
- we can never test an individual scientific hypothesis, but always and by necessity must test an entire theoretical group
- reason for this: cannot dispense with auxiliary hypothesis (concerning e.g. measuring apparatus) in deducing an observation sentence

Ludwik Fleck (1896-1961)

- *Entstehung und Entwicklung einer wissenschaftlichen Tatsache* (1935)
- scientist are enclosed in their and their community's preconceptions, and styles of thinking
- these styles have grown historically and are ineliminably social, i.e. a cultural product of a community at a certain place at a certain time
- development of science is not unidirectional, but its dynamics is determined by the cultural dynamics in the scientific communities
- progress is not cumulative
- truth is unattainable in scientific enquiry