Epistemology of Science

Lucas M. Schnorr

Comp. Syst. Perf. Analysis

Outline

About Science

Question 1: In less than 5 lines give a definition of "Science"

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"Le Robert" (wikipedia) Ce que l'on sait pour l'avoir appris, ce que l'on tient pour vrai au sens large. L'ensemble de connaissances, d'études d'une valeur universelle, caractérisées par un objet (domaine) et une méthode déterminés, et fondées sur des relations objectives vérifiables [sens restreint]

Trésor de la Langue Française Informatisé II. Ensemble structuré de connaissances qui se rapportent à des faits obéissant à des lois objective* (ou considérés comme tels) et dont la mise au point exige systématisation et méthode.

Dictionary of science and technology science noun

1. the study of the physical and natural world and phenomena, especially by using systematic observation and experiment
2. a particular area of study or knowledge of the physical world
3. a systematically organized body of knowledge about a particular subject

New Oxford Dictionary the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment : the world of science and technology.

1. a particular area of this : veterinary science | the agricultural sciences.
2. a systematically organized body of knowledge on a particular subject : the science of criminology.
3. archaic knowledge of any kind.

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  - Give 5 examples of non scientific facts

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- Question 3:
  1. Write in less than 5 lines a scientific hypothesis and propose an experiment to validate it
  2. Switch your hypothesis with your neighbor. Propose an experiment to invalidate the hypothesis.

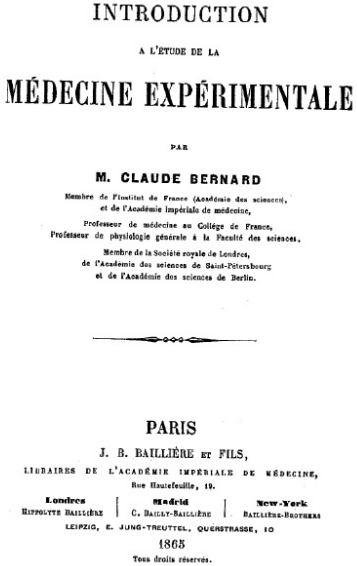
Outline

Claude Bernard (1813-1878) and the scientific method

3 steps of the scientific method:

1. observation of the reality is possible without premises ;
2. formulation of an hypothesis (theory) from scientist creativity ;
3. experimental verification by confrontation of the hypothesis with the reality (which is always true).

Inductivism (reasoning from the particular case to the general situation) : "The best theory is the one checked by the more numbers of facts."



INTRODUCTION

A L'ÉTUDE DE LA

MÉDECINE EXPÉRIMENTALE

PAR

M. CLAUDE BERNARD

Membre de l'Institut de France (Académie des sciences), et de l'Académie impériale de médecine,

Professeur de médecine au Collége de France, Professeur de physiologie générale à la Faculté des sciences,

Membre de la Société royale de Londres, de l'Académie des sciences de Saint-Pétersbourg et de l'Académie des sciences de Berlin.

PARIS

J. B. BAILLIÈRE ET FILS,

LIBRAIRES DE L'ACADÉMIE IMPÉRIALE DE MÉDECINE,

Rue Hautefeuille, 19.

Londres | Madrid | New-York

HIPPOLYTE BAILLIÈRE | C. BAILLY-BAILLIÈRE | BAILLIÈRE BROTHERS

LEIPZIG, E. JUNG-TREUTTEL, QUERSTRASSE, 10

1865

Tous droits réservés.

Karl Popper (1902-1994) and Falsifiability

- Criteria to separate science and non-science :
  Is scientific a theory that could be falsifiable, that could be submitted by empirical falsification = refutable by facts
- Asymmetry between verification and falsification. It is an logical and normative epistemology. Theories should be clearly formulated, as precisely as possible, can't be suppressed without a 'good reason' (falsification, or theory with "superior degree of falsifiability"), can't be immunized.
- The non-ended play of science.
  - World 1 : the world of physical objects and events, including biological entities
  - World 2 : the world of mental objects and events
  - World 3 : objective knowledge.

Karl Popper (1/2)

In the following text K.R Popper try to answer the questions : "When does a theory get a scientific status ?" "Is there a criteria to assert the nature or the scientific status of a theory ?"

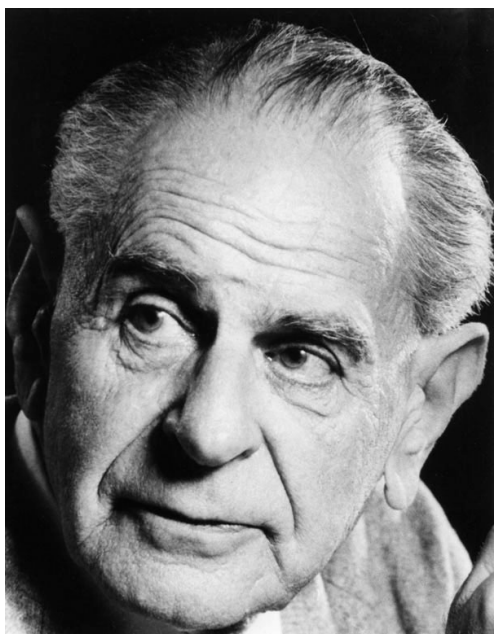
1. *It is easy to obtain confirmations, or verifications, for nearly every theory-if we look for confirmations.*
2. *Confirmations should count only if they are the result of risky predictions ; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible with the theory–an event which would have refuted the theory.*
3. *Every 'good' scientific theory is a prohibition : it forbids certain things to happen. The more a theory forbids, the better it is.*
4. *A theory which is not refutable by any conceivable event is nonscientific. Irrefutability is not a virtue of a theory (as people often think) but a vice.*
5. *Every genuine test of a theory is an attempt to falsify it, or to refute it. Testability is falsifiability ; but there are degrees of testability : some theories are more testable, more exposed to refutation, than others ; they take, as it were, greater risks.*

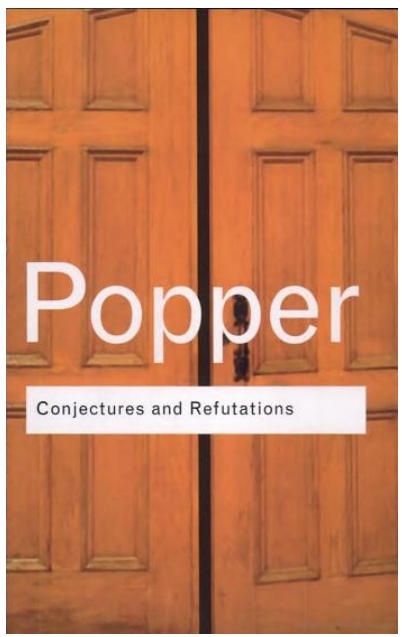
Karl Popper (2/2)

1. *Confirming evidence should not count except when it is the result of a genuine test of the theory ; and this means that it can be presented as a serious but unsuccessful attempt to falsify the theory. (I now speak in such cases of 'corroborating evidence'.)*
2. *Some genuinely testable theories, when found to be false, are still upheld by their admirers–for example by introducing ad hoc some auxiliary assumption, or by re-interpreting the theory ad hoc in such a way that it escapes refutation. Such a procedure is always possible, but it rescues the theory from refutation only at the price of destroying, or at least lowering, its scientific status.*

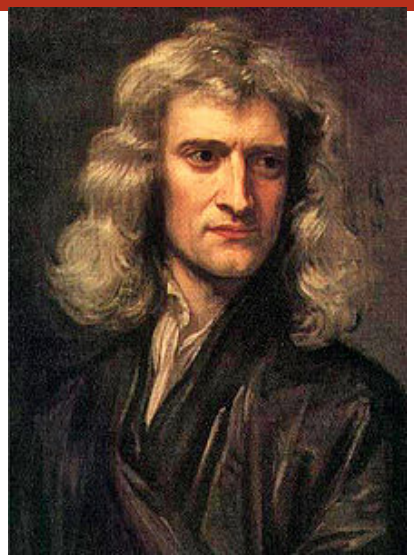
One can sum up all this by saying that the criterion of the scientific status of a theory is its falsifiability, or, refutability, or testability.

K.R. Popper
Conjectures and refutations.





Reproducibility of experimental results is the hallmark of science



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– ***Isaac Newton***, *February 1676*

Science allows to discover truth by building on previous discoveries.

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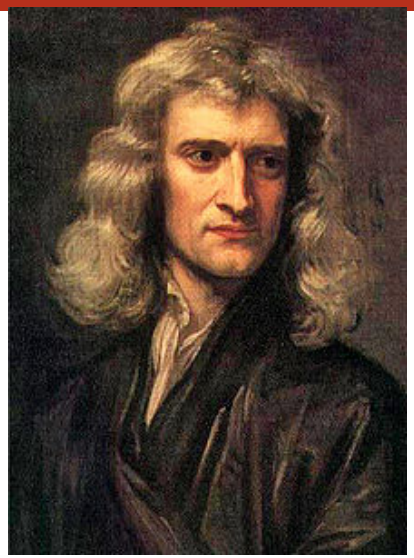

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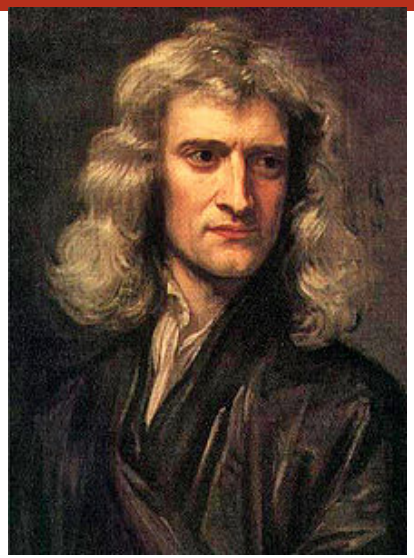

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- Theories cannot be proved correct but they can be disproved. Only a few stand the test of batteries of critical experiments.
- It is not all black and white. Many stories where scientists stick with their theories despite evidences they were even right to do so...

Further readings: A Summary of Scientific Method, Peter Kosso, Springer

Thomas Kuhn (1922-1996) : Science, a dynamical process

Phase 1 It exists only once and is the pre-paradigm phase, in which there is no consensus on any particular theory, though the research being carried out can be considered scientific in nature. This phase is characterized by several incompatible and incomplete theories. If the actors in the pre-paradigm community eventually gravitate to one of these conceptual frameworks and ultimately to a widespread consensus on the appropriate choice of methods, terminology and on the kinds of experiment that are likely to contribute to increased insights.

Phase 2 Normal Science, begins, in which puzzles are solved within the context of the dominant paradigm. As long as there is consensus within the discipline, normal science continues. Over time, progress in normal science may reveal anomalies, facts that are difficult to explain within the context of the existing paradigm. While usually these anomalies are resolved, in some cases they may accumulate to the point where normal science becomes difficult and where weaknesses in the old paradigm are revealed.

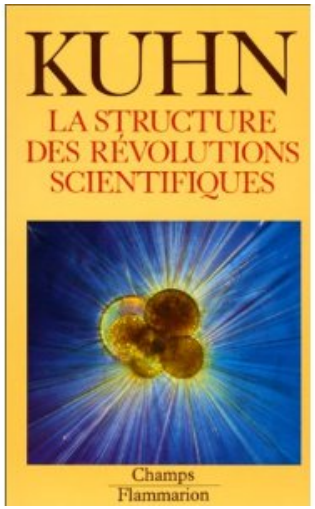
Phase 3 This phase is a crisis. Crises are often resolved within the context of normal science. However, after significant efforts of normal science within a paradigm fail, science may enter the next phase.

Phase 4 Scientific revolution is the phase in which the underlying assumptions of the field are reexamined and a new paradigm is established.

Phase 5 Post-Revolution, the new paradigm's dominance is established and so scientists return to normal science, solving puzzles within the new paradigm.

A science may go through these cycles repeatedly, though Kuhn notes that it is a good thing for science that such shifts do not occur often or easily

Thomas Kuhn



Pre-science

1. debate on the bases ;
2. no selection of facts ;
3. no scientific domain.

Normal Science existence of a paradigm, a matrix for the domain:

1. common language for the "tribe"
2. shared believes (ontologies, metaphors and analogies) ;
3. shared values (values, methodological, epistemological norms) ;
4. socialization examples. Normal science check that the paradigm is right, never contradictory facts

Scientific revolution

- Strong anomalies : fundamental questioning of the basic paradigms at a psychological, sociological, political level.
- Incommensurability between the old and the new paradigm.

Merton's Norms (1940): a sociological view of Science

This is the behavior observed in the scientific community:

1. Universalism: Sientific validity is independent of the sociopolitical status/personal attributes of its participants (origin, gender, sexuality, religion...).
2. Communality (before communism): *Nullius in Verba* (Take no one's word). Science means never having to say "trust me"
   - No secrecy, open communication is key
   - All scientists should have common ownership of scientific goods (intellectual property), to promote collective collaboration;
   - We say "Newton's law" to remember that Newton made the original discovery, but not because he has any property of this law.
3. Disinterestedness: Scientific institutions act for the benefit of a common scientific enterprise (finding the truth), rather than for the personal gain of individuals within them.
4. Organized skepticism: Scientific claims should be exposed to critical scrutiny before being accepted: both in methodology and institutional codes of conduct.
   - verify other's claims, nothing is sacred

These are our modern values/myths...

Imre Lakatos (1922-1974): Science, a social process

Research Program hard core values and fundamental beliefs, fundamental ontologies and methodology (ideology of the group) are never questioned ("negative heuristic").

Protecting belt theories confirming observed facts and protecting the hard core from critics.

- We falsify at the protecting belt level, never at the hard core level. We evaluate series of theories rather than falsifying a particular one (as Popper did).

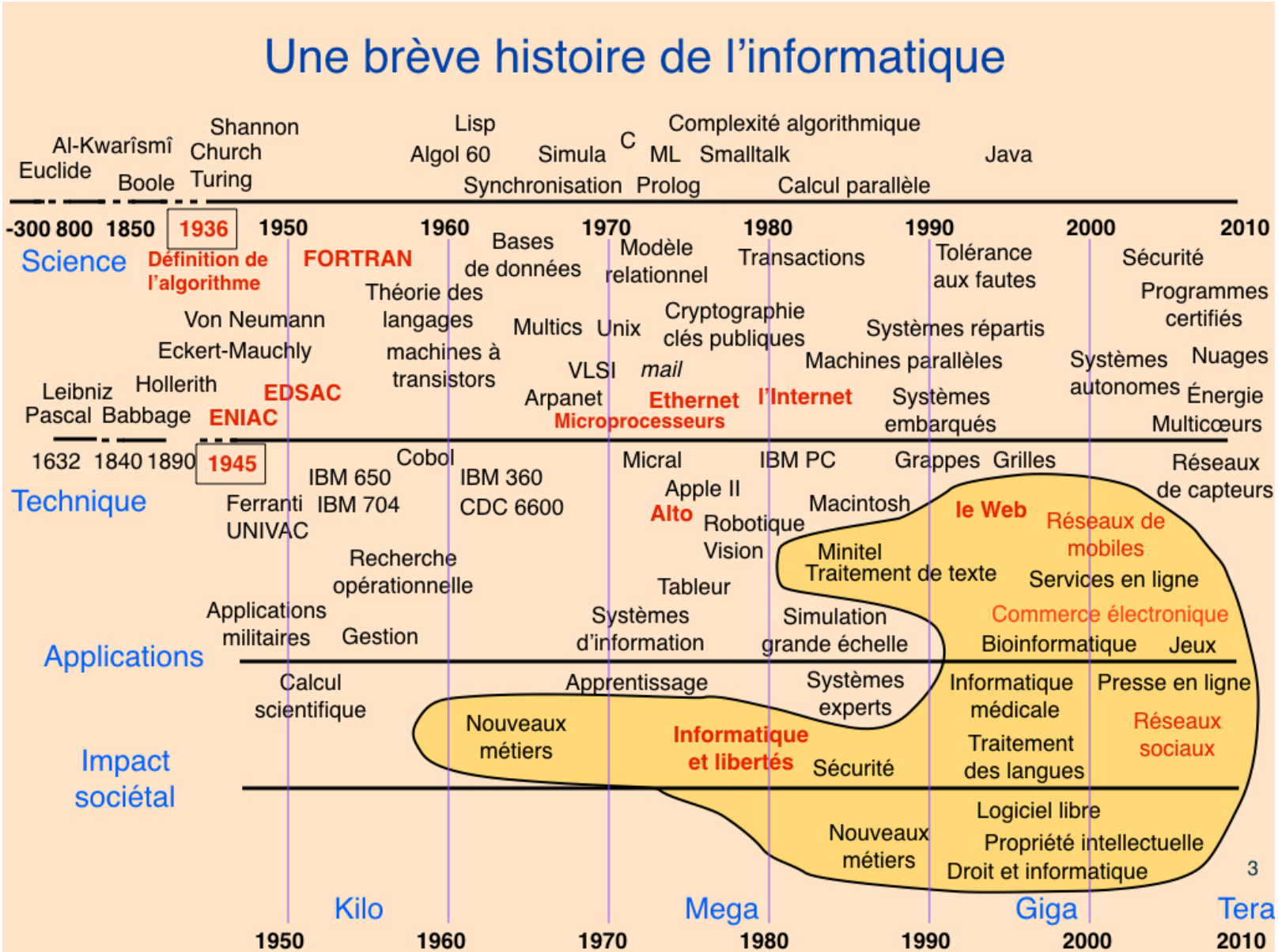
Main Science characterized by several concurrent research programs

Progressive Program progress at the theoretical level (increase coherence) and at the empirical level (new facts).

Degenerated Program no progress at the theoretical (no improvements) / empirical (no unpredictable facts) level

Outline

A short history of Computer Science



Courtesy of S. Krakowiak 2016

Defining Computer Science (Dowek and others)

Computing

- A science: Science of artificial... but not only
- A technology, an industry (Hardware, software, network, services,...)
- Applications: increasing area
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Computer Science Concepts

- Information: Representation, communication, compression,...
- Algorithm: Operative process
- Programming Language: link between levels of abstraction
- Architecture (Computing Engine): abstraction of the physical world
- Human in the loop

Methods: Back and forth between theory and experimentation. Automatic abstraction transform. Self-generated tools.

Human organization with social rules

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Modeling principles [J-Y LB]

- (Occam :) if two models explain some observations equally well, the simplest one is preferable
- (Dijkstra :) It is when you cannot remove a single piece that your design is complete.
- (Common Sense :) Use the adequate level of sophistication.

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Science is a Social Phenomena

- collaborative construction of knowledge
- dynamic evolution of knowledge