A bit of epistemology...
Scientific Methodology and Performance Evaluation

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SCHEDULING

1. September, 29 : **A bit of epistemology...** *J-M. Vincent*

2. October, 6 : **Methodological aspects of science, reproducible research, social aspects of science (peer review, communication, ...)** *A. Legrand*

3. October, 20 : **Causality, correlation and covariance : from observational vs. experimental data, observation → hypothesis → experiments and experiment design** *A. Legrand*

4. November 3 : **Design of Experiments basis (bias, replication vs. pseudo replication, randomization, blocks)** *J-M. Vincent A. Legrand*

5. November, 10 : **Descriptive statistics and data visualization** *A. Legrand*

6. November, 17 : **Modeling, basis of probabilities, estimation (confidence and bias)** *J-M. Vincent*

7. November, 24 : **Checking hypothesis, risk and test.** *J-M. Vincent*

8. December, 1 : **The linear model** *J.M. Vincent*

9. December, 8 : **Model adequation** *A. Legrand*

10. December, 15 : **Optimizing experiment design** *A. Legrand*

11. January, 5 : **Scientific method in computer science with human in the loop (1)** *N. Mandran*

12. January, 12 : **Scientific method in computer science with human in the loop (2)** *N. Mandran*

Follow ADE for the classroom usually

http://mescal.imag.fr/membres/arnaud.legrand/teaching/2016/M2R-SMPE.php

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RESEARCH IN COMPUTER SCIENCE...

Brainstorming n°1

Who is computer science if she was an animal ?

ABOUT SCIENCE...

Question nº1

In less than 5 lines give a definition of "Science".

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ABOUT SCIENCE...

Définition "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]

Définition Trésor de la Langue Française Informatisé

II. Ensemble structuré de connaissances qui se rapportent à des faits obéissant à des lois objectives (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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RESEARCH IN COMPUTER SCIENCE

Brainstorming nº2

Give 5 examples of scientific facts in computer science

Give 5 examples of non scientific facts

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ABOUT SCIENCE...

Question n°2

In less than 5 lines give the definition of a scientific fact.

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SCIENTIFIC FACT

A scientific fact is an **hypothesis** that have been confirmed by a **specific** experience.

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ABOUT SCIENCE...

Question n°3

Step 1

Write in less than 5 lines a scientific hypothesis and propose an experiment to validate it

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ABOUT SCIENCE...

Question n°3

Step 1

Write in less than 5 lines a scientific hypothesis and propose an experiment to validate it

Step 2

Switch your hypothesis with your neighbor.
Propose an experiment to invalidate the hypothesis.

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CLAUDE BERNARD 1813-1878

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 check by the more numbers of facts."

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CLAUDE BERNARD 1813-1878

Wikipedia

Electronic French version

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KARL POPPER 1902-1994

- 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 epistemology logical and normative. 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's text

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In the following text K.R Popper try to answer the questions : "*When a theory get a scientific status ?*" "*Does it exist 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.

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6 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'.)

7 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. (I later described such a rescuing operation as a 'conventionalist twist' or a 'conventionalist stratagem'.)

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.
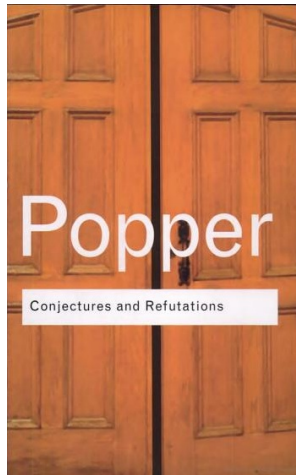**K.R. Popper**, Conjectures and refutations.

Thanks to C. Grasland

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KARL POPPER 1902-1994
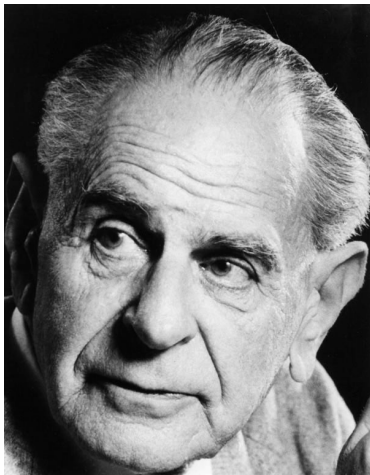
Wikipedia

Electronic version

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.[4]

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.   (source wikipedia)

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THOMAS KUHN 1922-1996

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) ;
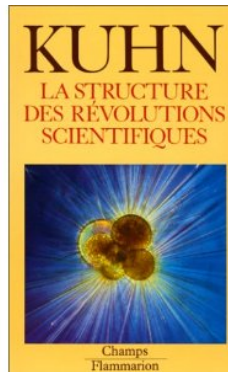4. socialization examples. Normal science check that the paradigm is right, never contradictory facts

Scientific revolution

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

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THOMAS KUHN 1922-1996
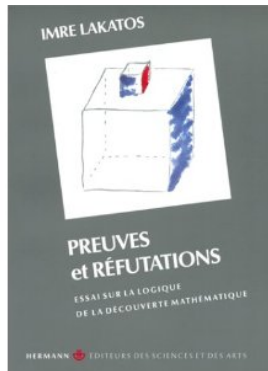

Paradigms

Electronic version

IMRE LAKATOS 1922-1974

- ▶ **Research Program : hard core** values et fundamental believes fondamentales ontologic and methodologic (ideology of the group), 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 concurrents.
- ▶ **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

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IMRE LAKATOS 1922-1974

Wikipedia

Electronic version

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Une brève histoire de l'informatique

	Shannon		Lisp			Complexité algorithmique			
Al-Kwarîsmî	Church		Algol 60	Simula	C ML Smalltalk		Java		
Euclide	Turing								
Boole				Synchronisation Prolog		Calcul parallèle			

| -300 800 1850 | **1936** | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |

Science — **Définition de l'algorithme** — **FORTRAN** — Bases de données — Modèle relationnel — Transactions — Tolérance aux fautes — Sécurité

Théorie des langages — Multics Unix — Cryptographie clés publiques — Systèmes répartis — Programmes certifiés

Von Neumann — machines à transistors — VLSI — *mail* — Machines parallèles — Systèmes autonomes — Nuages

Eckert-Mauchly

Leibniz Hollerith **EDSAC** — Arpanet — **Ethernet** — **l'Internet** — Systèmes embarqués — Énergie

Pascal Babbage **ENIAC** — **Microprocesseurs** — Multicœurs

| 1632 1840 1890 | **1945** | | | | | | | |

Technique — IBM 650 — Cobol — IBM 360 — Micral — IBM PC — Grappes Grilles — Réseaux de capteurs

Ferranti IBM 704 — CDC 6600 — Apple II — Macintosh — **le Web** — **Réseaux de mobiles**

UNIVAC — **Alto** — Robotique — **Minitel** — Services en ligne

Recherche opérationnelle — Vision — Traitement de texte

Tableur

Applications militaires Gestion — Systèmes d'information — Simulation grande échelle — Commerce électronique — Jeux

Applications — Apprentissage — Bioinformatique

Calcul scientifique — Systèmes experts — Informatique médicale — Presse en ligne

Impact sociétal — Nouveaux métiers — **Informatique et libertés** — Sécurité — Traitement des langues — **Réseaux sociaux**

Nouveaux métiers — Logiciel libre — Propriété intellectuelle — Droit et informatique

3

| | Kilo | | Mega | | Giga | | Tera |

| 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |

(source S. Krakowiak 2016)

COMPUTER SCIENCE

Computing

- A **science**
  Science of artificial... but not only

- A **technology**, an industry
  Hardware, software, network,
  services,...

- **Applications**
  increasing area

- **Social impact**
  Numerical/Information society

Computer Science

- **Concepts : representation of the object**
  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**

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SYNTHESIS

Scientific Method

Falsifiability is the logical possibility that an assertion can be shown false by an observation or a physical experiment. [Popper 1930]

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Modeling (abstract representation) comes before experimenting

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Modeling (abstract representation) comes before experimenting

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

...now it's your turn

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RÉFÉRENCES I

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RÉFÉRENCES II

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