Scientific Methodology and Experimental Evaluation

A short positionning

{Arnaud.Legrand,Jean-Marc.Vincent}@univ-grenoble-alpes.fr

Université Grenoble-Alpes and INRIA
Laboratoire d'Informatique de Grenoble
Team INRIA POLARIS

Master of Computer Science of Grenoble
October 2024

METHODOLOGY FOR SCIENTIFIC RESEARCH

UGA UFR IM²AG Université Grenoble Alpes

DESCRIBE SCIENCE

Explain in one sentence the word science to your young brother/sister (12 years)

DESCRIBE SCIENCE

Explain in one sentence the word science to your young brother/sister (12 years)

Give an example to illustrate and to justify your statement

RESEARCH...

An exquisite cadaver

Cadavre Exquis with André Breton, Jacques Hérold, Yves Tanguy, Victor Brauner *Figure* 1934, from MOMA website

RESEARCH...

An exquisite cadaver

Cadavre Exquis with André Breton, Jacques Hérold, Yves Tanguy, Victor Brauner *Figure* 1934, from MOMA website

Describe a scientific situation (one big sentence)

- When
- Where
- Who
- How (action, verb)
- What
- Why

Once upon a time, in an ugly swamp, a green giant was fishing big crabs for dinner.

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]

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

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.

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.

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]

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

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.

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.

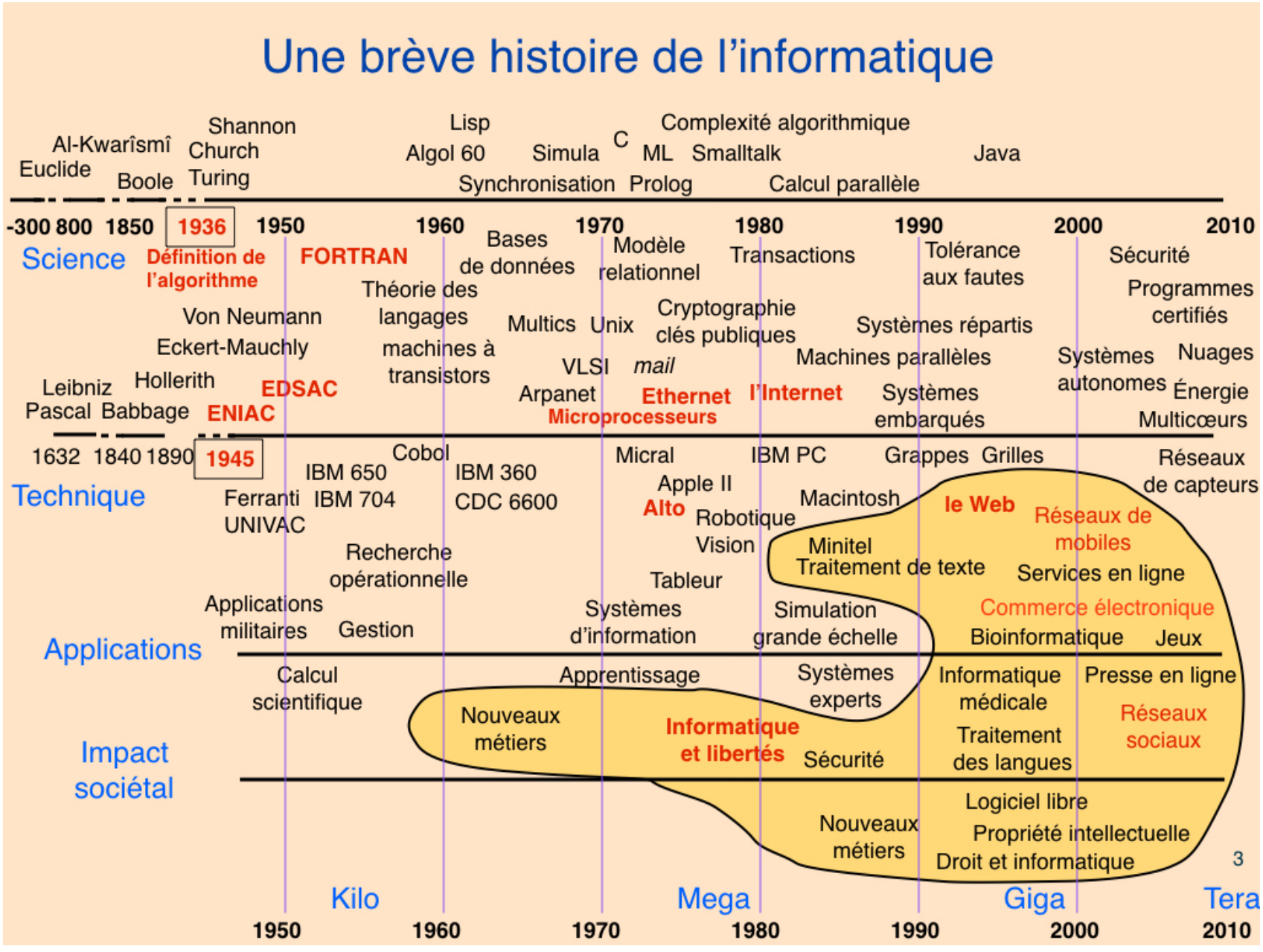
structured knowledge on the "physical world" associated to universal methods (observation/experiment)

METHODOLOGY FOR SCIENTIFIC RESEARCH

COMPUTER SCIENCE

If computer science is an monument, what would she be ?

use one or two keywords to explain why.



(source S. Krakowiak 2016)

COMPUTER SCIENCE

Computing

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

COMPUTER SCIENCE

Computing

- A **science**
  Science of artificial... but not only
- A **technology**, an industry
  Hardware, software, network, services,...

COMPUTER SCIENCE

Computing

- A **science**
  Science of artificial... but not only
- A **technology**, an industry
  Hardware, software, network, services,...
- **Applications**
  increasing area

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

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

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

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

COMPUTER SCIENCE

Computing

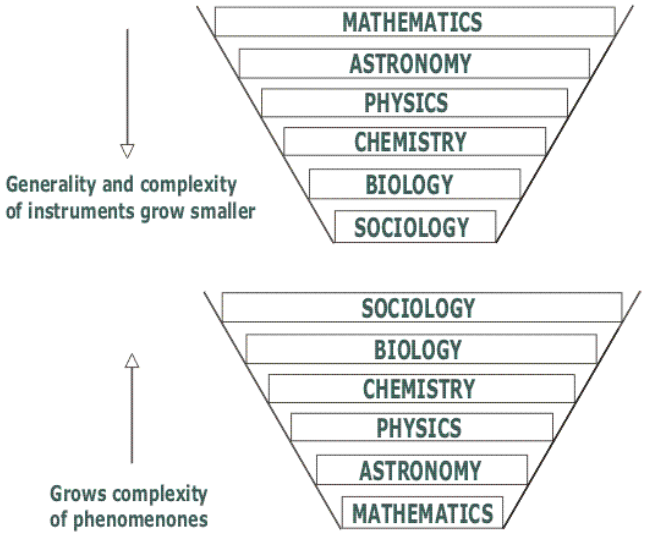
- A **science**
  Science of artificial... but not only
- A **technology**, an industry
  Hardware, software, network, services,...
- **Applications**
  increasing area
- **Social impact**
  Numerical/Information society

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**

COMPUTER SCIENCE POSITION

Classification of Sciences

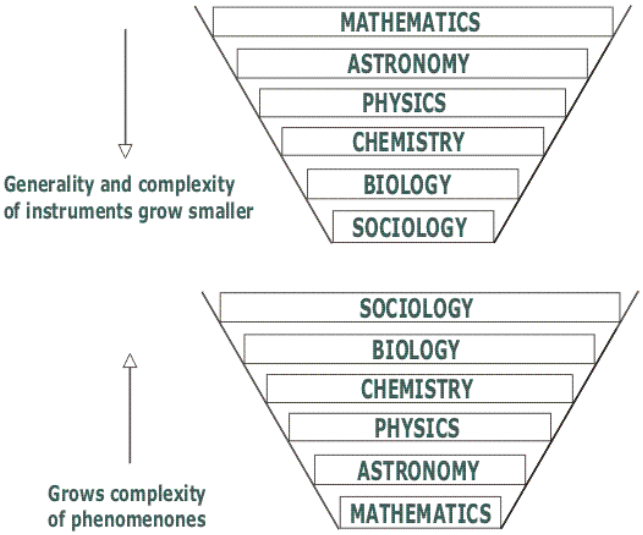


By Gregory Podgorniak , CC BY-SA 3.0, Wikipedia

Auguste Comte (1798-1857)

COMPUTER SCIENCE POSITION

Classification of Sciences



By Gregory Podgorniak , CC BY-SA 3.0, Wikipedia

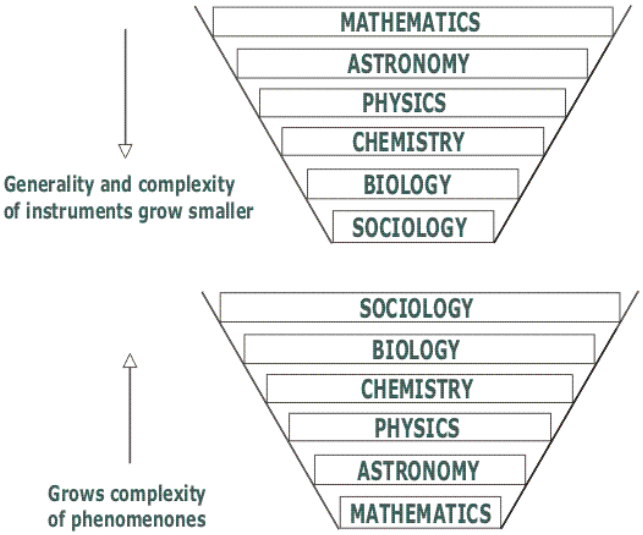
Auguste Comte (1798-1857)

Analytic / Synthetic

- Mathematics : analytic *a priori*
- Sciences of nature : synthetic *a posteriori*

COMPUTER SCIENCE POSITION

Classification of Sciences



By Gregory Podgorniak , CC BY-SA 3.0, Wikipedia

Auguste Comte (1798-1857)

Analytic / Synthetic

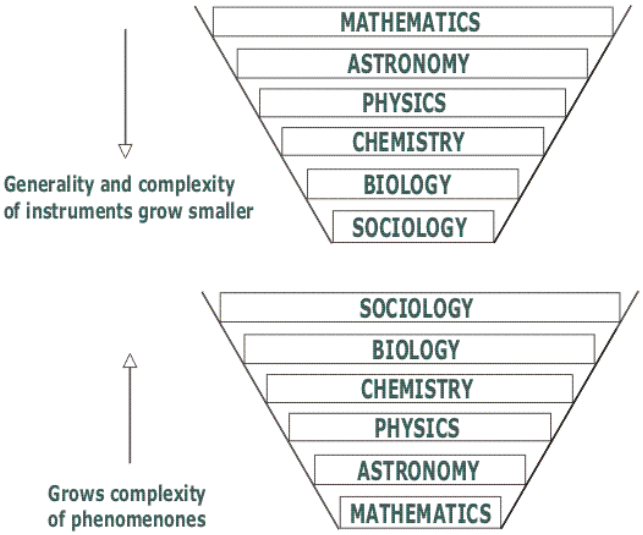
- Mathematics : analytic *a priori*
- Sciences of nature : synthetic *a posteriori*

Objects

- Information
- Languages
- Machines
- Algorithms

COMPUTER SCIENCE POSITION

Classification of Sciences



By Gregory Podgorniak , CC BY-SA 3.0, Wikipedia

Auguste Comte (1798-1857)

Analytic / Synthetic

- Mathematics : analytic *a priori*
- Sciences of nature : synthetic *a posteriori*

Objects

- Information
- Languages
- Machines
- Algorithms

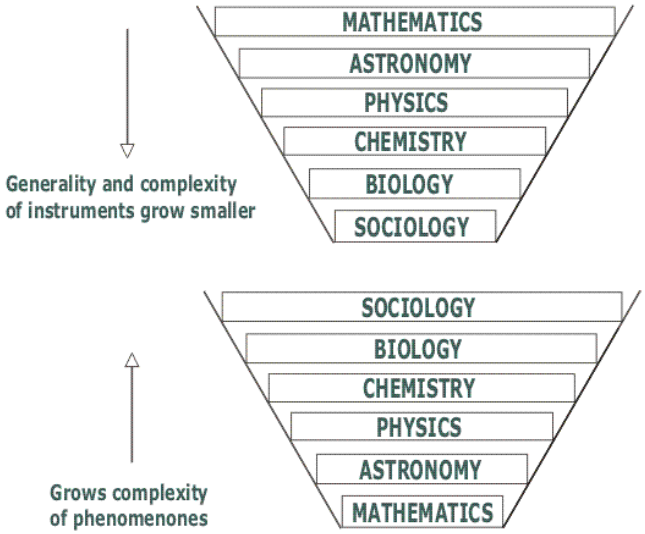
Methods

- Judgement *a posteriori*
- Judgement *a priori*

2nd Int. Conf. on the History and Philosophy of Computing, October 28-31, 2013, Paris, France.

COMPUTER SCIENCE POSITION

Classification of Sciences



By Gregory Podgorniak , CC BY-SA 3.0, Wikipedia

Auguste Comte (1798-1857)

Analytic / Synthetic

- Mathematics : analytic *a priori*
- Sciences of nature : synthetic *a posteriori*

Objects

- Information
- Languages
- Machines
- Algorithms

Methods

- Judgement *a posteriori*
- Judgement *a priori*

2nd Int. Conf. on the History and Philosophy of Computing, October 28-31, 2013, Paris, France.

Thus, not only Informatics requires to extend the usual classifications of sciences to include analytic a posteriori sciences, but it also destabilizes the usual distinction between a priori and a posteriori sciences and the usual classifications of sciences, that attempt to classify sciences alone and not sciences and technologies together. Gilles Dowek (2013)

METHODOLOGY FOR SCIENTIFIC RESEARCH

1 SCIENCE : What is this thing called Science ?

2 COMUTER SCIENCE : Where is Computer Science ?

3 **SCIENTIFIC METHOD : Facts and causality**
- Claude Bernard and the scientific hypothesis
- Karl Popper and refutability
- Thomas Kuhn and the dynamicity of science
- Imre Lakatos and concentric sciences

4 COMMUNITY

5 SYNTHESIS

SCIENTIFIC FACTS

Give one example of a scientific fact and explain why you call it *scientific*

SCIENTIFIC FACTS

Give one example of a scientific fact and explain why you call it *scientific*

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

SCIENTIFIC HYPOTHESIS

Step 1

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

SCIENTIFIC HYPOTHESIS

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.
Evaluate the obtained conclusion

CLAUDE BERNARD 1813-1878

The Scientific Method

3 steps (loop) :

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).

CLAUDE BERNARD 1813-1878

The Scientific Method

3 steps (loop) :

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."

CLAUDE BERNARD 1813-1878

Wikipedia

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 HIPPOLYTE BAILLIÈRE | Madrid C. BAILLY-BAILLIÈRE | New-York BAILLIÈRE-BROTHERS

LEIPZIG, E. JUNG-TREUTTEL, QUERSTRASSE, 10

1865

Tous droits réservés.

Electronic French version

SCIENCE : CONJECTURE AND REFUTATIONS

Read the text

- identify main keywords (and their definition)
- identify examples and their role in the text (W5H)

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

From Karl Popper's text

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.

From Karl Popper's text

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.

From Karl Popper's text

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

From Karl Popper's text

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

From Karl Popper's text

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.

From Karl Popper's text

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 ?*"

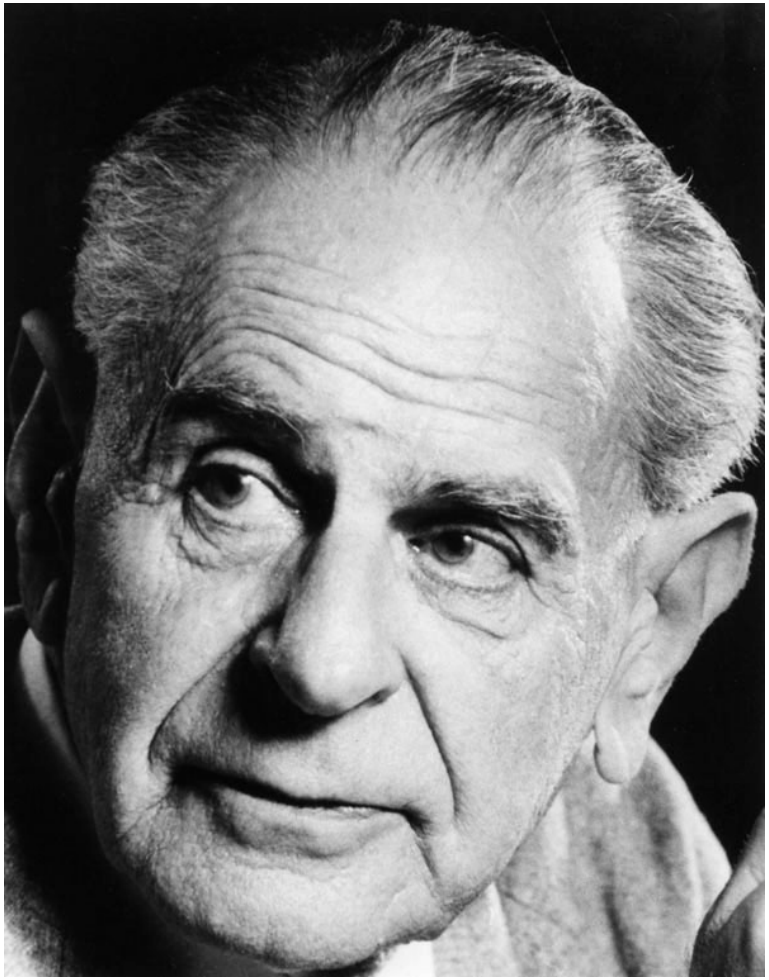
1. It is easy to obtain confirmations, or verifications, for nearly every theory-if we look for confirmations.
2. Confirmations should count only if they are the result of risky predictions ; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible 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.

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'.)

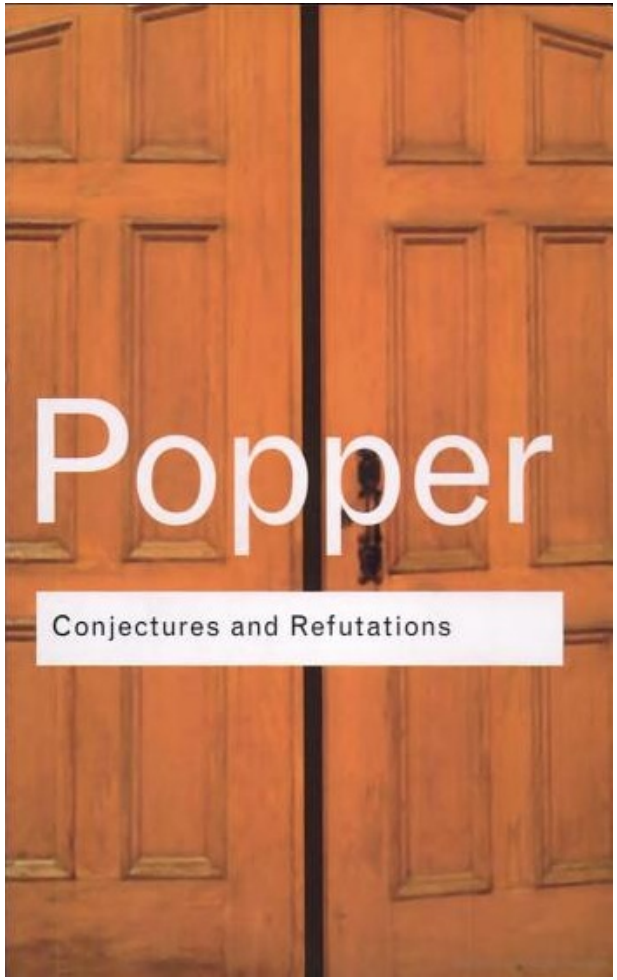
One can sum up all this by saying that the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability.
K.R. Popper, Conjectures and refutations.

Thanks to C. Grasland

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.

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)

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.

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)

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.

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)

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.

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)

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)

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 :

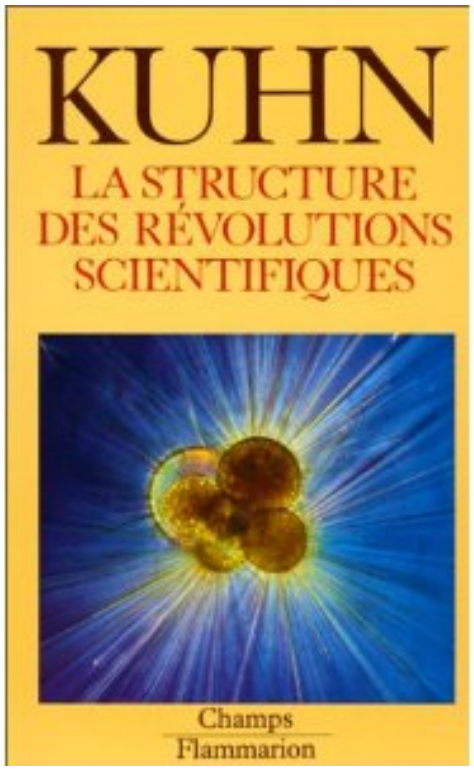
1. common language for the "tribe"
2. shared believes (ontologies, metaphors and analogies) ;
3. shared values (values, methodological, epistemological norms) ;
4. socialization examples. Normal science check that the paradigm is right, never contradictory facts

Scientific revolution

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

THOMAS KUHN 1922-1996

Paradigms



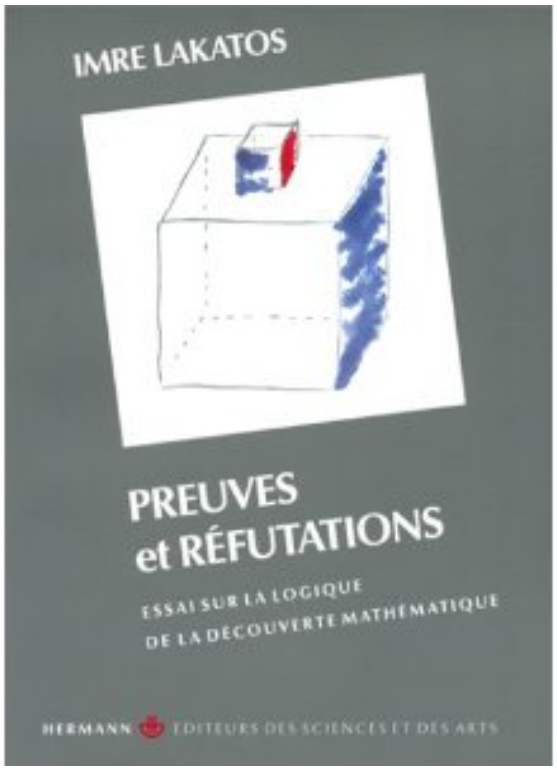
Electronic version

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.
- **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

IMRE LAKATOS 1922-1974

Wikipedia



Electronic version

METHODOLOGY FOR SCIENTIFIC RESEARCH

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)
- Publications

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)
- Publications
- Conferences

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)
- Publications
- Conferences

Institutionality of research

- Science management (Local Universities, National Government,)

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)
- Publications
- Conferences

Institutionality of research

- Science management (Local Universities, National Government,)
- Structures of research (CNRS, INRIA,...)

SCIENCE : A SOCIAL OBJECT

Individual searchers

- Individual basic work
- point to point collaboration

Research teams and Labs

- Small groups of searchers : common goal
- Technical support (resources)
- Social management

International Community

- International groups (IEEE, ACM, Unesco,...)
- Publications
- Conferences

Institutionality of research

- Science management (Local Universities, National Government,)
- Structures of research (CNRS, INRIA,...)
- International groups (Europe, bilateral agreements,...)

METHODOLOGY FOR SCIENTIFIC RESEARCH

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world
- Use testable ideas

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world
- Use testable ideas
- Relies on evidence

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world
- Use testable ideas
- Relies on evidence
- Involves the scientific community

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world
- Use testable ideas
- Relies on evidence
- Involves the scientific community
- Leads to ongoing research

SCIENCE CHECKLIST

How scientific is it ?

From Understanding Science (Berkeley)

- Focuses on the *natural* world
- Aims to explain the natural world
- Use testable ideas
- Relies on evidence
- Involves the scientific community
- Leads to ongoing research
- Benefits from scientific behavior

SYNTHESIS

Scientific Method

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

SYNTHESIS

Scientific Method

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

Modeling (abstract representation) comes before experimenting

SYNTHESIS

Scientific Method

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

Modeling (abstract representation) comes before experimenting

Scientific principles [J-Y LB]

- (Occam :) if two models/theories 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.

SYNTHESIS

Scientific Method

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

Modeling (abstract representation) comes before experimenting

Scientific principles [J-Y LB]

- (Occam :) if two models/theories 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.

Science is a Social Phenomena

- collaborative construction of knowledge
- dynamic evolution of knowledge

...now it's your turn ...

RÉFÉRENCES I

Bernard, C. (1865), *Introduction à l'étude de la médecine expérimentale*, J.-B. Baillère et fils.

Carnap, R. (1995), *An Introduction to the Philosophy of Science*, Dover Publications.

Chalmers, A. F. (1990), *Qu'est-ce que la science ?*, Le Livre de Poche.

Chalmers, A. F. (2013), *What Is This Thing Called Science ?*, Hackett Publishing Company, Inc.

Godfrey-Smith, P. (2003), *Theory and Reality : An Introduction to the Philosophy of Science (Science and Its Conceptual Foundations series)*, University Of Chicago Press.

Kosso, P. (2011), *A Summary of Scientific Method*, Springer.

Kuhn, T. S. (1996), *The Structure of Scientific Revolutions*, The University of Chicago Press.

Kuhn, T.-S. (2008), *La structure des révolutions scientifiques*, Flammarion.

Lakatos, I. (1976), *Proofs and Refutations : The Logic of Mathematical Discovery*, Cambridge University Press.

Lakatos, I. (1984), *Preuves et Réfutations : essai sur la logique de la découverte mathématique*, Hermann.

Popper, K. (2002), *Conjectures and Refutations : The Growth of Scientific Knowledge*, Routledge.

UGA IM²AG UFR Université Grenoble Alpes

Explain in one sentence the word science to your young brother/sister (12 years)

Give an example to illustrate and to justify your statement

Explain in one sentence the word science to your young brother/sister (12 years)

Give an example to illustrate and to justify your statement

Explain in one sentence the word science to your young brother/sister (12 years)

Give an example to illustrate and to justify your statement

When

Where

Who

How (action, verb)

What

Why