

Research Methodology

Lecture 1: Science

Professor: Dr. Libertario Demi

libertario.demi@unitn.it



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General information



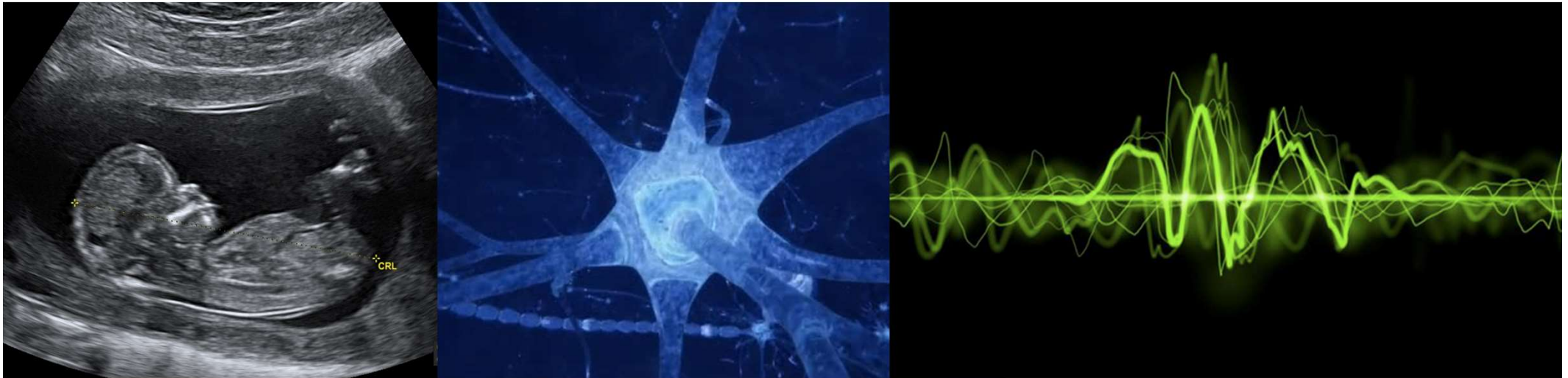
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Me

- My office hours: Wednesdays from 14:30 to 16:30 (please take an appointment by email)
- I teach **Digital Signal Processing** and **Ultrasound Technologies for Medical Applications** at the Master of Science in Information and Communications Engineering



General information



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Material

- Course Slides (available online)

Others

- Class attendance: **60% mandatory**
- Exam: within approx. 2 months (hard submission deadline) from the end of the course you have to submit an IEEE format short paper (4-pages max) which describes your research and references to the literature on the topic.

<https://www.ieee.org/conferences/publishing/templates.html>

Exam: Modality



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- Writing a short paper (4-pages max) related to your qualifying/thesis proposal
 - this paper must be written following the guidelines of the PhD School qualifying exam and using the **IEEE format**
<https://www.ieee.org/conferences/publishing/templates.html>
 - all the writing **must be original**, namely there cannot be sentences which are copied from other papers. The students who will commit an act of (self)plagiarism will fail the exam. On top of this, depending on the gravity of the fact, it will be asked to expel these students from the University
 - it must be **understandable** by all the students of the course
 - all papers must be electronic, in **PDF format**
- Reviewing three papers written by the colleagues (these will be assigned to you by the end of the course)

The examination is passed if, after no more than one iteration, the paper is graded with **WEAK ACCEPT** or better grade.

Exam: Grading



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- A maximum of 10 out of 10 plus honors.
- Grades are computed as follows:
2/3 paper quality, 1/3 reviewing quality.

Exam: Grading



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- A maximum of 10 out of 10 plus honors.
- Grades are computed as follows:
2/3 paper quality, 1/3 reviewing quality.
 1. All Papers must be submitted **by May 24th** (Send your paper to libertario.demi@unitn.it)
 2. Review Allocation **by May 31st** (I will send you three papers to review)
 3. Reviews Due **by June 21st** (you will send the review to the me and to the other reviewers, I will then send the reviews to the author. Authors need to include their email in the pdf)
 4. Authors need to reply (send the rebuttal to me) to the reviewers **by June 28th**
 5. Reviews can either accept or request additional modifications, and respond to the author **by July 5th**
 6. Authors have to reply to the final reviews **by July 12**. To pass the exam the paper must be graded higher or equal to week accept.

Timetables



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- March 18, 2019 13:00 - 17:00 "Garda" room (Povo 1)
- March 19, 2019 13:00 - 17:00 A203 lecture room (Povo 1)
- March 20, 2019 13:00 - 17:00 A221 lecture room (Povo 1)
- March 21, 2019 13:00 - 17:00 A207 lecture room (Povo 1)
- March 22, 2019 13:00 - 17:00 A224 lecture room (Povo 1)

What is science?



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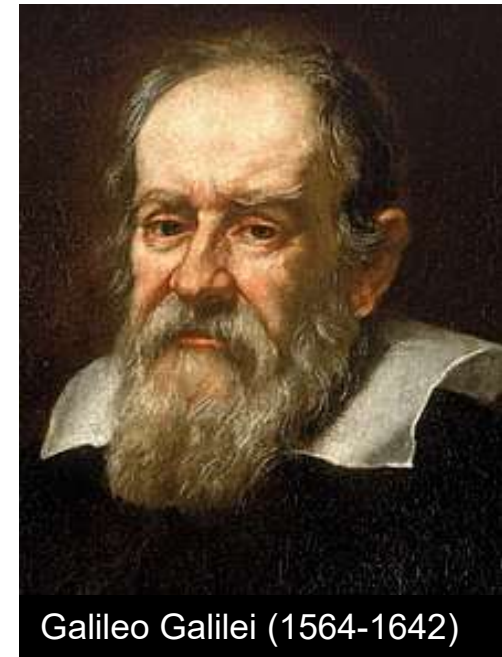
What is science?



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Science is a method



Galileo Galilei (1564-1642)

What is science?

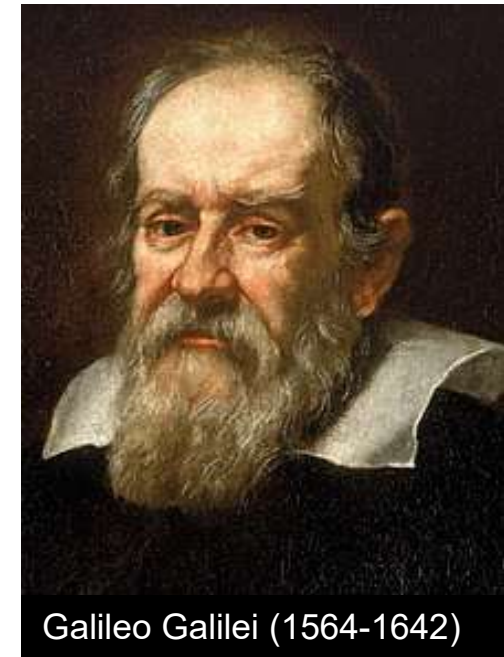


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Science is a method

- Formulation of an hypothesis or theory



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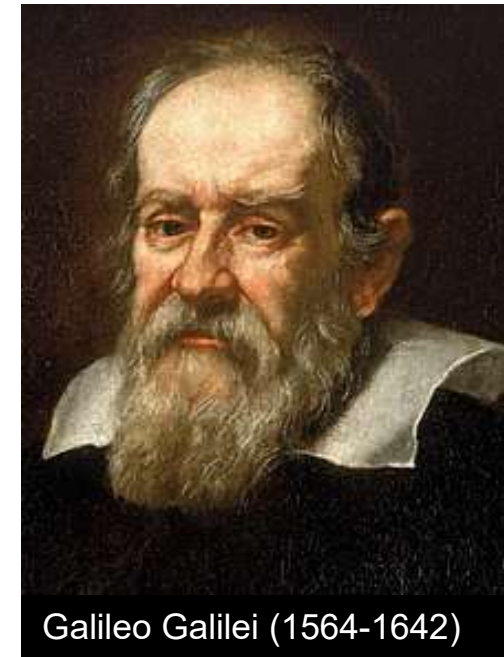


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Science is a method

- Formulation of an hypothesis or theory
- Gathering of data



Galileo Galilei (1564-1642)

What is science?

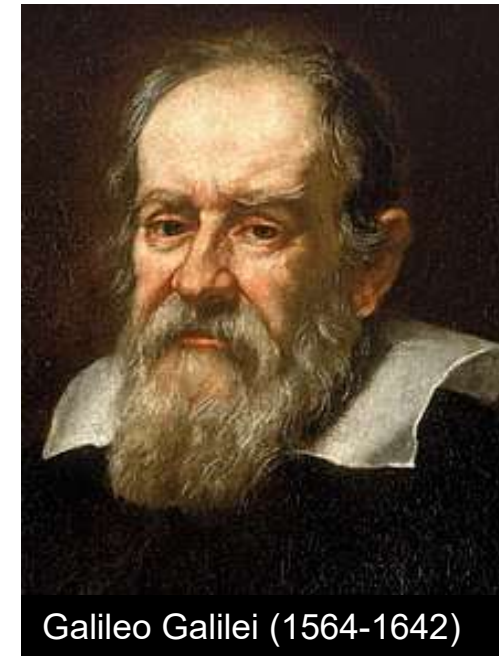


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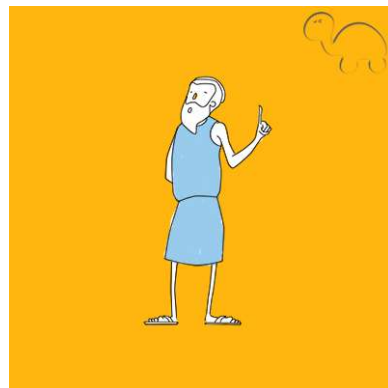
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Science is a method

- Formulation of an hypothesis or theory
- Gathering of data
- Rigorous analysis of the data



Galileo Galilei (1564-1642)



Logic

$$A = e^{j2\pi} - \frac{e^{j4\pi}}{e^{j6\pi} + e^{j8\pi}} - \frac{\cos(2\pi n)}{2}$$

Mathematics

What is science?



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Science is a method

- Formulation of an hypothesis or theory
- Gathering of data
- Rigorous analysis of the data
- Conclusion



Isaac Newton (1643-1727)

Three Laws of motion

$$F = ma$$

What is science?



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Max Planck (1858 -1947)

Scientific discovery and scientific knowledge have been achieved only by those who have gone in pursuit of it without any practical purpose whatsoever in view.

What is science?

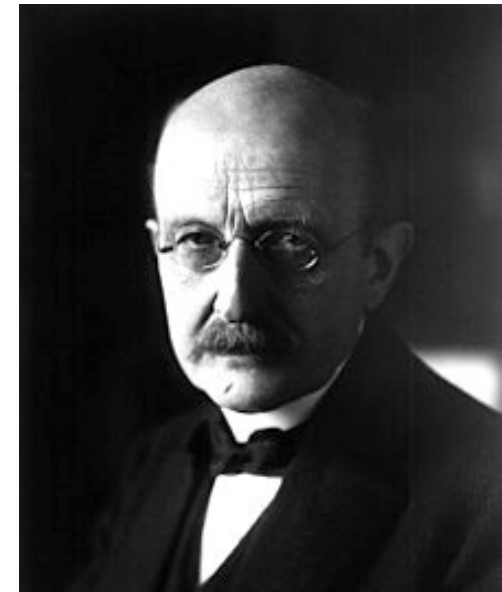


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There is no science without

- Questions (why?)



Max Planck (1858 -1947)

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What is science?



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There is no science without

- Questions (why?)
- Evidence (either experimental or theoretical)



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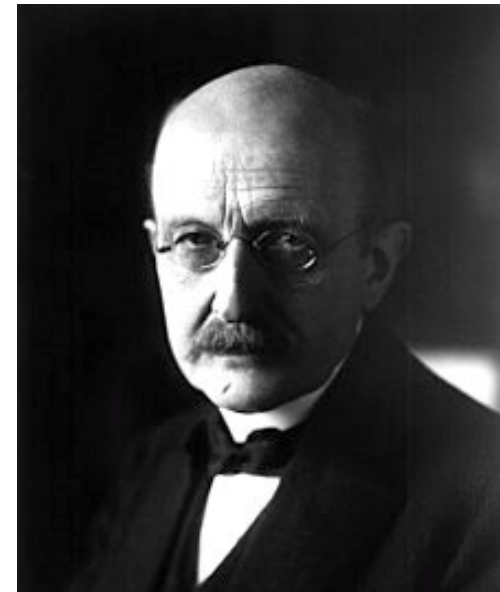


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There is no science without

- Questions (why?)
- Evidence (either experimental or theoretical)
- Clarity and transparency of the method (reproducibility)



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There is no science without

- Questions (why?)
- Evidence (either experimental or theoretical)
- Clarity and transparency of the method (reproducibility)
- Honesty and acceptance of errors



Max Planck (1858 -1947)

Scientific discovery and scientific knowledge have been achieved only by those who have gone in pursuit of it without any practical purpose whatsoever in view.

Why science?



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Why science?



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Science has multiple functions

Creative function: it creates and promotes knowledge



1972 – The Blue Marble Apollo 17 mission

Why science?



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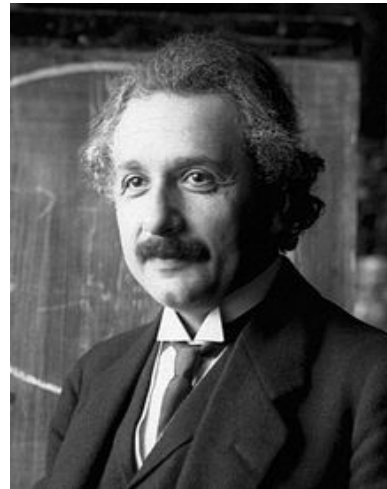
Science has multiple functions

Creative function: it creates and promotes knowledge

Critical function: it encourages the discovery and revision of mistakes and errors



1972 – The Blue Marble Apollo 17 mission



1916 – General Relativity by Albert Einstein

Why science?



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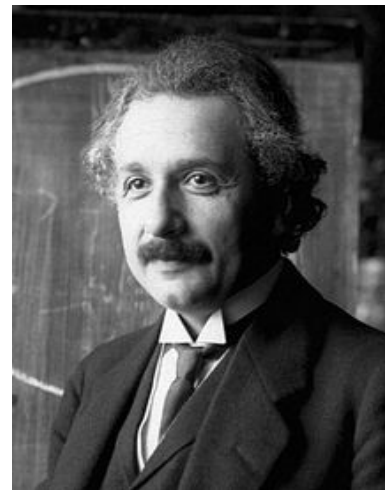
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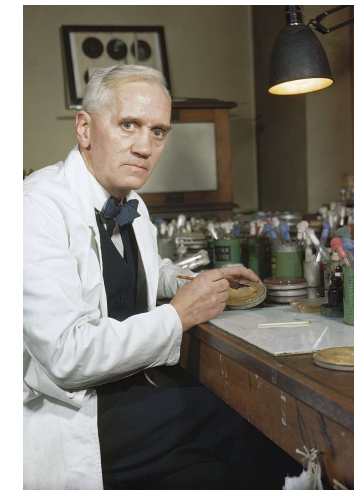
Predictive function: it provides explanations, predictions and control of complex phenomena, true simplified models of reality



1972 – The Blue Marble Apollo 17 mission



1916 – General Relativity by Albert Einstein



1928 - First antibiotic (Penicillin G)
by Alexander Fleming

To what does science applies?



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To what does science applies?



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Areas of Science

Physical Sciences: about the fundamental nature of matter and energy

Biological Science : about living things

Behavioral Science: about human behavior, individuals and groups

Earth sciences: about nonliving matter on Earth and elsewhere in the Universe

To what does science applies?



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Areas of Science

Physical Sciences: about the fundamental nature of matter and energy

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Is not always possible to strictly apply the scientific method to every scientific question, **e.g. what is the effects of ionizing radiations on infants?**



What is engineering?



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What is engineering?



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Engineering is the **application** of knowledge acquired by means of the scientific method to the innovation, design, construction, operation, control and maintenance of structures, systems, materials, devices, processes, and organizations.

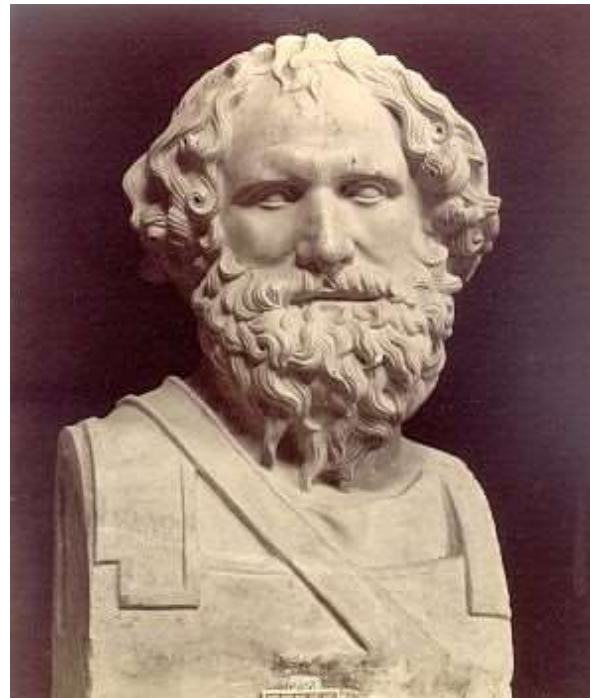
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Archimede (288-212 BC)



Leonardo da Vinci (1452 - 1519)

What is engineering?



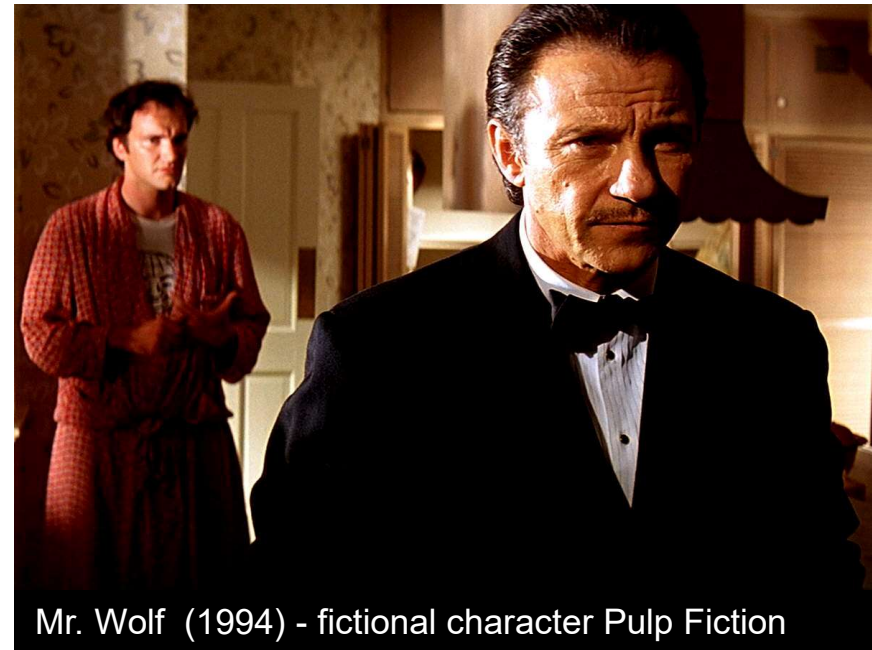
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Engineering is the **application** of knowledge acquired by means of the scientific method to the innovation, design, construction, operation, control and maintenance of structures, systems, materials, devices, processes, and organizations.

The engineer is in essence Mr. Wolf



Mr. Wolf (1994) - fictional character Pulp Fiction

What is engineering?



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The class of engineering is then defined by the **field of application**

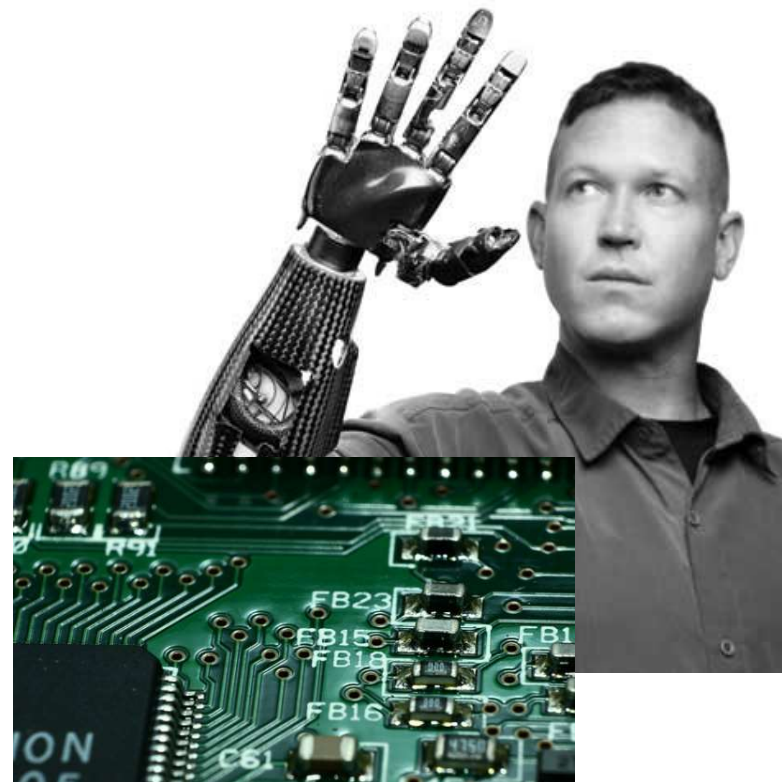
Telecommunication Engineering

Biomedical Engineering

Electrical Engineering

Information Engineering

Computer Engineering



What about us?



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Doctorate School in Information and Communication **Technologies**



What about us?

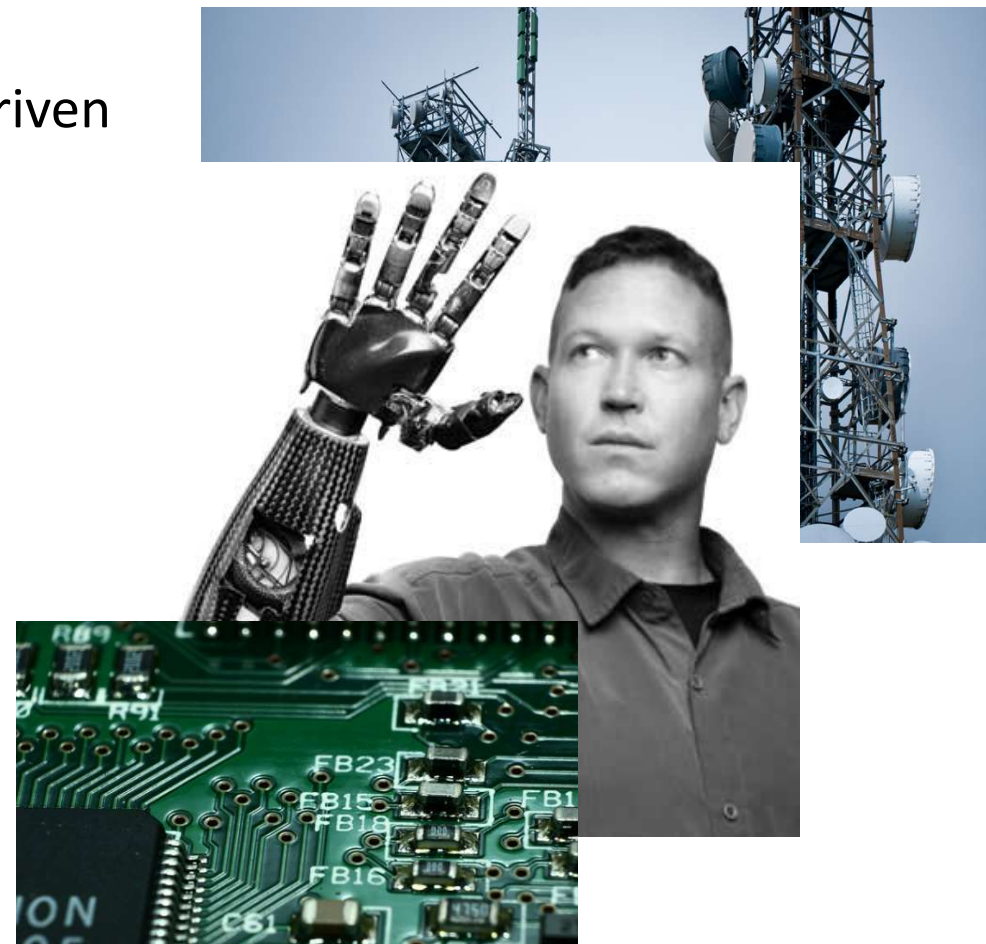


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Doctorate School in Information and Communication **Technologies**

We deal with the technologically driven evolution of fields like ICT, BioTech, Energy, Exploration, Human Computer Interaction...



What about us?



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We deal with the technologically driven evolution of fields like ICT, BioTech, Energy, Exploration, Human Computer Interaction...

And **research** new, better solutions.



What is Research?



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What is Research?



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Research is the process of discovery of new knowledge

What is Research?



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Research is the process of discovery of new knowledge

Basic Research

- About fundamental properties of objects, their relationship and behavior
 - Theoretical Research
 - Experimental Research

Applied Research

- About the utility of objects and their behavior
 - Theoretical Research
 - Experimental Research

What is Research?



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Research is the process of discovery of new knowledge

Scientific research is an attempts to describe/ explain/control real phenomena
(e.g., $\text{force} = \text{mass} \times \text{acceleration}$).

What is Research?



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But bare in mind:

There is no absolute scientific truth, and every model is wrong

What is Research?



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Research is the process of discovery of new knowledge

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But bare in mind:

There is no absolute scientific truth, and every model is wrong

Scientific statements must be **testable and reproducible** (a paper is good if I can redo what is written in this paper)

Scientific Knowlege should represent the most accurate view of the real world that is possible at a given time, and it should be always open to correction.

It should actually look forward for it.

How do we know we are doing scientific research?



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How do we know we are doing scientific research?



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We stick to the methods

And of course different methods (philosophy of science) have been devised on how to acquire new knowledge

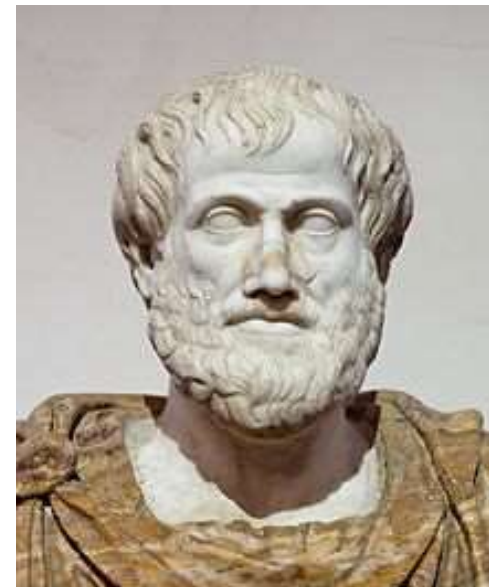
Syllogism



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Aristotele (374-322 BC)

Syllogism



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A categorical syllogism consists of three parts:

Major premise (A is B)

Minor premise (C is A)

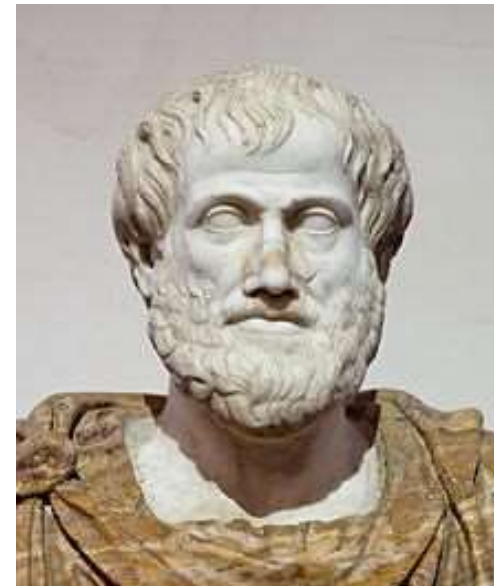
Conclusion (C is B)

Example

MajP – All humans are mortal

MinP – All Europeans are humans

Conclusion – All Europeans are mortal



Aristotele (374-322 BC)

Syllogism



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This is an example of **deductive reasoning** where starting from two verified facts we deduce a third.

However this is sometimes not sufficient.

Syllogism



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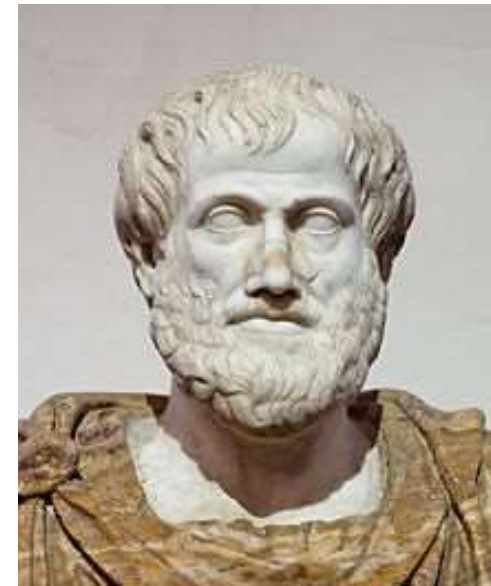
Conclusion (C is B)

Counter-example

MajP – All things with a mass attract each other
(univ. gravitation law)

MinP – All protons have a mass

Conclusion – All protons attract each other



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This is an example of **deductive reasoning** where starting from two verified facts we deduce a third.

However this is sometimes not sufficient.

Empiricism



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Empiricism



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Knowledge can only derive from our senses and experience, it cannot be deduced or derived without it.

Empiricism



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Knowledge can only derive from our senses and experience, it cannot be deduced or derived without it.

There are two approaches in empiricism:

- Induction (from specific to general)
- Deduction (from general to specific)

Induction



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After observing a large number of A's, and for all these A's a specific feature B is observed then one can conclude that all A's have the feature B

Data Collection – Measurements – Observations



Data Analysis



Generalization - Theory

Deduction



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Starting from a theory generated from the observation, a specific set of measurements is performed and then analyzed to prove the theory

Generalization - Theory



Data Collection – Measurements – Observations



Data Analysis

Induction Vs. Deduction

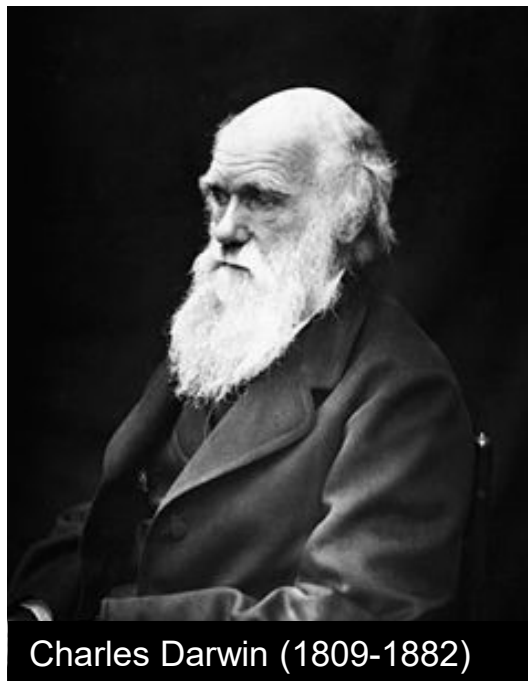


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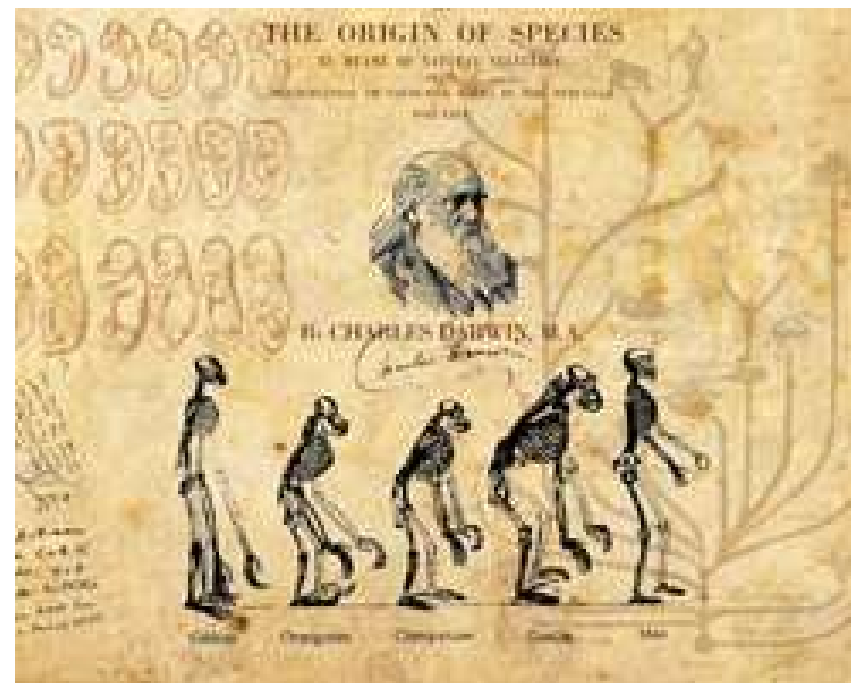
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Induction: basically no guidelines to follow to perform your measurements, very useful to gain knowledge and understating of a phenomenon

Deduction: you need to have a theory on which to based your measurements, but then you can be much more efficient in the definition of your measurements



Charles Darwin (1809-1882)



Positivism



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Method originated from a movement characterized by the absolute trust in scientific progress and for the attempt to apply the scientific method to all the areas of knowledge



Auguste Comte (1798-1857)

Positivism



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Method originated from a movement characterized by the absolute trust in scientific progress and for the attempt to apply the scientific method to all the areas of knowledge



1. **Define the phenomenon** under investigation
2. Make an **hypothesis** on the expected findings under defined conditions
3. **Test** the hypothesis experimentally
4. **Analyse** the results **and iterate** the process improving both hypothesis and experimental conditions in order to develop a **theory**.

Auguste Comte (1798-1857)

Hypothesis



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It is crucial to identify a good hypothesis, i.e. a clearly defined and experimentally demonstrable effects.

When metal heats up, it expands.

Hypothesis



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It is crucial to identify a good hypothesis, i.e. a clearly defined and experimentally demonstrable effects.

When metal heats up, it expands.

What can go wrong with your hypothesis?

- It is wrong
- It is correct, but it will be rejected by the experimental results

Theory



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A set of statements, systematically ordered, reflecting a well defined part of the real world.

Theories should be

- Rational => logically consistent (no ambiguity or imprecision)
- Relevant => it should be clear how it relates to the real world
- Extensible => able to explain more, or better, or complement what previously known

Can we do otherwise?



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So far we have always trying to develop knowledge by verifying, can we do otherwise?

Since it is true that even after verifying N observations, no matter how large is N , it is possible that the observation $N+1$ produces a contradiction.

Falsificationism

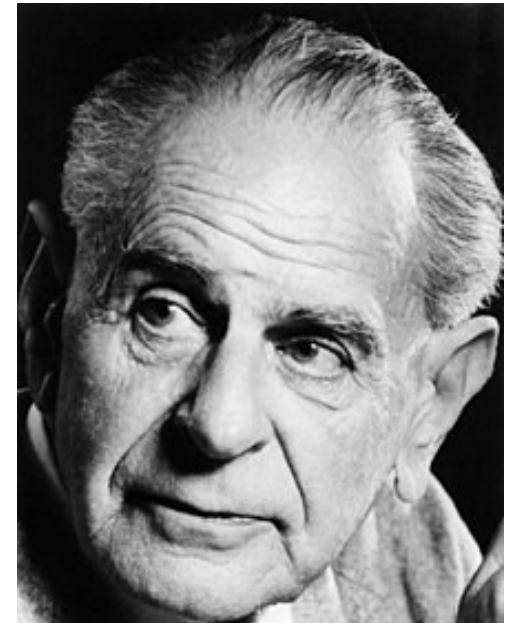


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Hypotheses must be falsifiable in order to be scientific; if a claim is not able to be refuted it is not a scientific claim.

1. **Define the phenomenon** under investigation
2. Make an **hypothesis** on the expected findings under defined conditions
3. **Test** the hypothesis experimentally to find out where it is not correct
4. If hypothesis is falsified then it is modified. Hypothesis is considered reliable if it has survived many attempts to falsify it
5. **Analyse** the results **and iterate** the process improving both hypothesis and experimental conditions in order to develop a **theory**.



Karl Popper (1902-1994)

Positivism and Falsificationism



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Both assume that scientific knowledge about the world can be gained **only through experiments**, where observations determine the validity of theories, and that there is a steady increase in our understanding of scientific phenomena.

Starting in the 50's, revisions to these concepts have been introduced and debated

Beyond Positivism and Falsificationism



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Starting in the 50's, revisions to these concepts have been introduced and debated:

- Objective vs. subjective Science (consider for instance scientists' perception of the world)
- Impact of unobservable parts on observable parts (consider for instance medicine)
- Paradigms (Kuhn): Most of the time the scientists in a discipline operate under a **paradigm** (normal science).

Beyond Positivism and Falsificationism



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A paradigm is a (temporarily) accepted basis of a discipline, a generally accepted schema for selecting and solving problems, basic assumptions and also explanations.

E.g. the use of ultrasound to inspect the lung.

Changes of paradigm



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Within a paradigm: if there are contradictions between specific theories, based on a paradigm, and reality, so not the paradigm is questioned but the theory and measurement methods etc.

Changes of paradigm



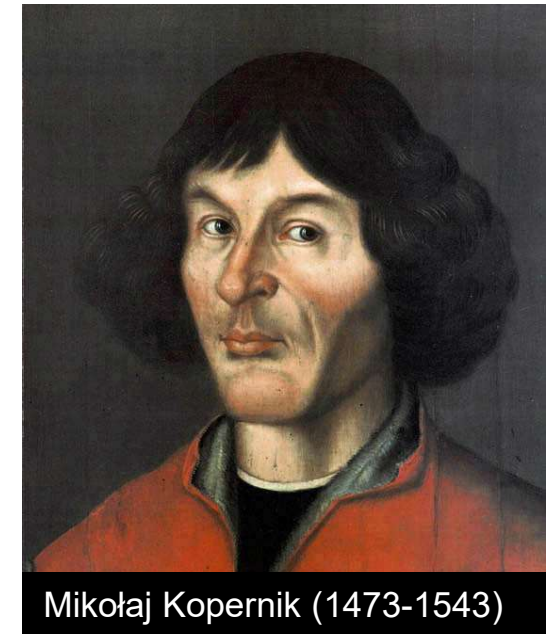
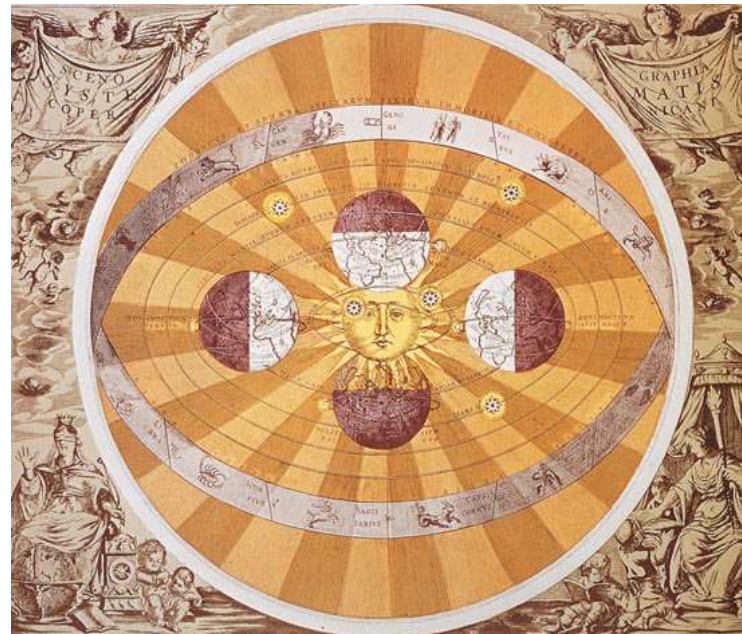
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Within a paradigm: if there are contradictions between specific theories, based on a paradigm, and reality, so not the paradigm is questioned but the theory and measurement methods etc.

But paradigms change: from Ptolemy to Copernicus.

Paradigm change = change of scientific view of the world, scientific revolution



Mikolaj Kopernik (1473-1543)

Philosophy of Science Today



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Post positivism: accepts that theories, background, knowledge and values of the researcher can influence what is observed.

Objectivity is researched by recognizing the possible effects of biases, and both quantitative and qualitative approaches are considered to be valid.

Relativism: importance of social factor, science defined by group. There is no objective truth.

Realism: real world is separate from our perception, science allows us to get closer.

Philosophy of Science Today



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Philosophy of Science is a very complex and very interesting matter.

Philosophy of Science Today



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This is an oversimplified description.

Philosophy of Science Today



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This is an oversimplified description.

However, it should have provided an idea about science and about the fact that science is defined by us.

Philosophy of Science Today



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The most important thing which defines science is that **science is open to change**, there is no dogma, and that the focus is on improving our ability to interact with and beyond our self.

Philosophy of Science Today



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The most important thing which defines science is that **science is open to change**, there is no dogma, and that the focus is on improving our ability to interact with and beyond our self.

...and also an idea of methods of science that most of you will use during your PhD and later.

Who do we do research with?



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We do it within a community, and in general terms **science is defined by the scientific community**

Science as a social institution. The goal of science is a consensus of rational opinion over the widest possible field.

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Science as a social institution. The goal of science is a consensus of rational opinion over the widest possible field.

But there are constraints

- Education
- Tradition
- Sequence of gaining knowledge – existing theories (paradigm) may limit perception

And generally accepted norms

Scientific norms



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- Communism
Scientific knowledge is the property of everyone
Scientists have to publish their results
- Universalism
There is no privileged sources of scientific knowledge
The only criterion is competence
- Disinterestedness
Refers to a lack of bias or a lack of self-interest
- Originality
Work should be original
- Skepticism
Be always critical especially with respect to your own work

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Instruments of the scientific community



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- “Invisible” colleagues (communication and promotion networks)
Journals, Conferences, Projects
- Peer Review system
Independent peers review papers and editors accept or reject a publications
- Reward System
Recognition among peers
Invited talks
Program Chair of Conferences
Prizes
Top Prizes
Salary
Contract money

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Misconduct in Science



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Misconduct in Science



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In Science integrity is the most important thing, and this is easy to say but very hard to guarantee in practice.

Misconduct is incompatible with Science.

Misconduct in Science



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In Science integrity is the most important thing, and this is easy to say but very hard to guarantee in practice.

Misconduct is punished in Science.



She was 'the next Steve Jobs.' Now, Theranos founder Elizabeth Holmes is charged with fraud

Marco della Cava | USA TODAY
Published 9:12 AM EDT Mar 15, 2018



Misconduct in Science

Theranos

- Blood tests which required only about 1/100 to 1/1,000 of the amount of blood ordinarily needed.
- Founded in 2003 by then-19-year-old Elizabeth Holmes
- More than 700 million \$ from venture capitalists and private investors,
- A \$10 billion valuation in 2013 and 2014.
- In 2016 investigative reporter John Carreyrou of The Wall Street Journal questioned the validity of Theranos' technology.
- In February 2016, Theranos announced that it would permit a complete a validation study of its technology
- On March 14, 2018, Theranos, Holmes, and former company president Ramesh Balwani were charged with "massive fraud", and
- On June 15, 2018, the U.S. Attorney for the Northern District of California announced the indictment of Holmes on wire fraud and conspiracy charges. Balwani was also indicted on the same charges.



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- Fraud
 - By fabrication*
 - By falsification*
- Plagiarism
 - use of someone's else words (ideas, pictures, ...) without giving proper credit*
- Conflict of Interest
 - avoid personal issues: Review the paper of a friend or paper of a competing group*

Misconduct in Science



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- Failing to retain research data for a reasonable period
- Maintaining inadequate research records
- Refusing to give peers access to research materials
- Inappropriate statistics to enhance the significance of research findings
- Inadequately supervising research subordinates
- Misrepresenting speculations as fact
- Releasing results without providing sufficient data
- Selective reporting of research
- Interference
- Self-plagiarism

Misconduct in Science



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Scientific Commandments:

- Be Honest
- Never manipulate data
- Be precise
- Be fair with regard to priority and ideas
- Be without bias with regard to the data and ideas of your rival
- Do not make compromises in trying to solve a problem

Hans Mohr, 1979



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End of lecture 1