

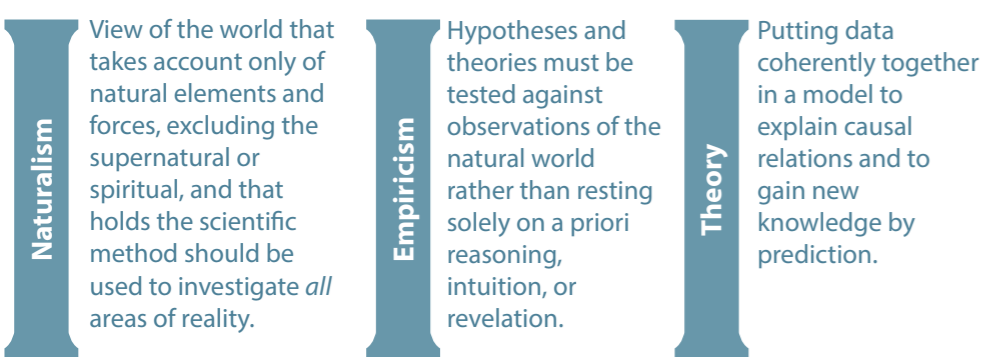
PHILOSOPHY OF SCIENCE & CRITICAL THINKING

What is science?

Working definition of science

Systematic collective endeavor that builds and organizes knowledge in the form of testable explanations and predictions about the universe.

Three pillars of science



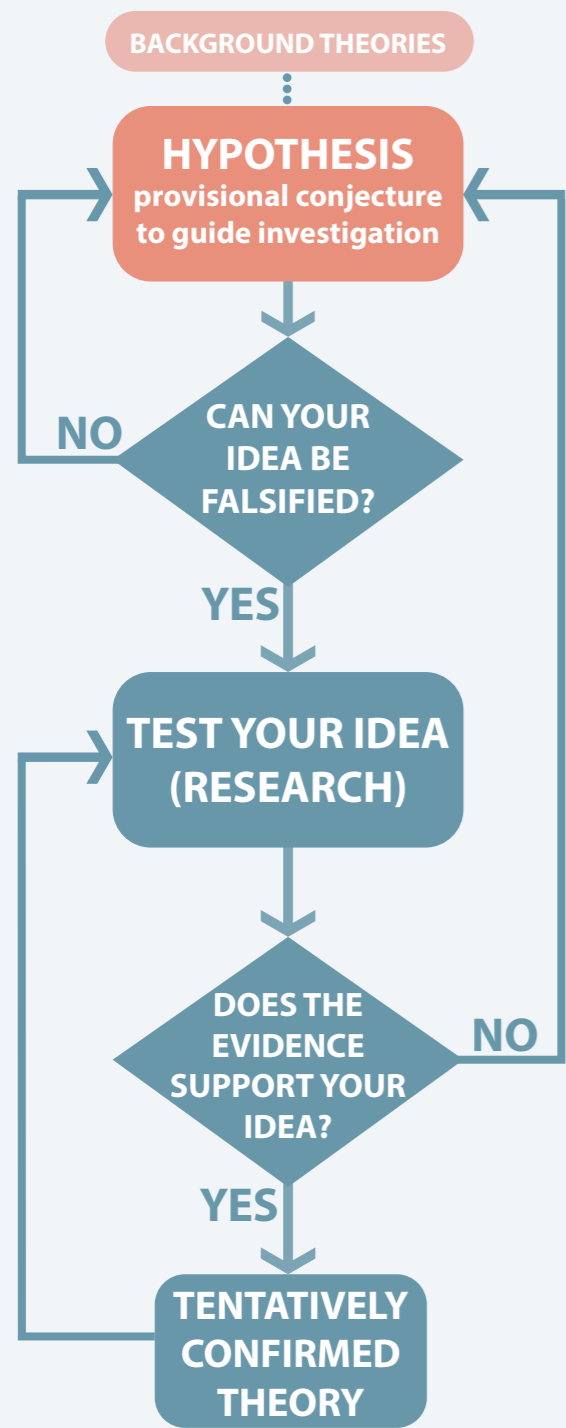
Some characteristics of science

- dynamic
- self-correcting
- collective enterprise
- finding & interpreting empirical evidence
- cumulative body of knowledge
- unnatural and counterintuitive nature of science
- creating coherent theories for explaining and predicting data
- fallibilistic (acknowledging that we make errors)
- probabilistic (100 % certainty is often impossible)
- knowledge produced without reference to our social context
- science is the characteristic defining feature of our age
- no forbidden zones: all things and all knowledge claims are open to question



THE SCIENTIFIC PROCESS

How does science work?



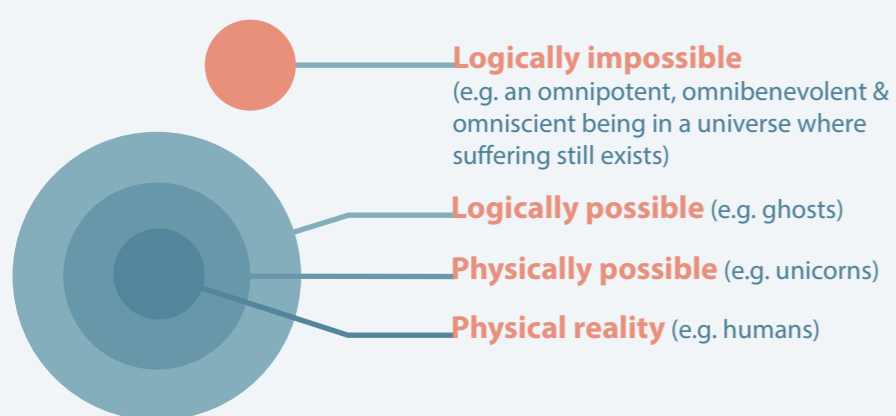
SOME PROBLEMS IN SCIENCE

What are the problems in philosophy of science?

- Reductionism** Is there a Theory of Everything? Can psychology, for example, be reduced to physics?
- Ethics of science** Are there moral limits to what science can do? For example, genetically modified organisms (GMO) and animal experimentation. Who is responsible for the negative consequences of (the application of) science in technology, e.g. the atomic bomb, mining.
- Causation** What is causation? Is there a connection of real necessity between cause and effect?
- Realism-antirealism** Do scientific constructs, like unobservables (e.g. subatomic particles), really exist?
- Induction** What can justify our reliance on inductive inference (axiom of uniformity of nature)? How can we be certain that the current natural laws will also apply in the future?
- Justification versus discovery** Social scientists (e.g. Bloor, Latour) and historians of science (e.g. Kuhn) reveal that what scientist actually do (*context of discovery*) does not comply with what philosophers of science (like Popper) say that science is (*context of justification*).
- Methodology** Is there a general scientific method or a diversity of methods? Do social sciences and the humanities (soft sciences) use the same scientific method as the physical (hard) sciences?
- Scientific revolutions & paradigm shifts** Scientists work within and against the background assumptions of an unquestioned theory or set of beliefs (paradigm). A paradigm shift (or scientific revolution) is a change in the basic assumptions within the ruling theory of science. According to Kuhn scientific revolutions are noncumulative and the new paradigm is incommensurable with the one it replaces.
- Truth relativism** The claim that knowledge (including science) is relative to time and place, that there is no absolute truth or validity, having only relative, subjective value according to differences in perception and consideration. There are no absolute truths, i.e., that truth is always relative to some particular frame of reference, such as a language or a culture (cf. cultural relativism). The opposite of relativism is objectivism / scientific naturalism.

THE ONTOLOGY OF IMAGINATION

How does our imagination differ from reality?



Three scientific methods

Deduction

- Valid inference from more general premises to a more specific conclusion. It's always 100% certain, but it only works in closed systems.
- Top-down reasoning.
- Examples: Mathematics, logic.
- Problem: How do we find the basic premisses (i.e. axioms) to build the deductive system?

Induction

- Method of logical reasoning, which derives general laws from particular facts or examples (data).
- Bottom-up reasoning.
- We have a natural habit for induction. Humans are induction machines.
- Based on empirical observations.
- Observations: Swan 1 is white; swan 2 is white; swan 3 is white. Conclusion: All swans are white
- Examples: Physics, chemistry.
- Problems:
 - 1) Assumes the uniformity of nature (i.e. that the laws of nature will not change over time).
 - 2) Underdetermination: the available evidence is insufficient to prefer one theory to another.

Abduction / Inference to the best explanation

- Inference to the best explanation based on the (little) evidence at hand.
- Probability: educated guess based on the available evidence.
- Searching for the most plausible explanation.
- Used mostly in the social sciences, jurisprudence, archeology, etc.

SOME FORMAL LOGIC

How to get 100% certainty?

Syllogism (Aristotle)

Premiss 1: All humans are mortals. $a \rightarrow b$
 Premiss 2: Socrates is a human. $c \rightarrow a$
 Conclusion: Socrates is mortal. $c \rightarrow b$

Propositional logic (Frege)

Modus ponens

Premiss 1: If it rains, the streets get wet. $p \rightarrow q$
 Premiss 2: It rains. p
 Conclusion: The street gets wet. q

Modus tollens

Premiss 1: If it rains, the streets get wet. $p \rightarrow q$
 Premiss 2: The streets are not wet. $\neg q$
 Conclusion: It does not rain. $\neg p$

Fallacy of affirming the consequent

Premiss 1: If it rains, the streets get wet. $p \rightarrow q$
 Premiss 2: The streets are wet. q
 Conclusion: It rains (INVALID) p (INVALID)
 (There are other reasons why the streets could be wet)

PROBABILITY SCALE OF KNOWLEDGE

How reliable are our knowledge claims?

Reason is the faculty of proportioning judgment to evidence, after first weighing the evidence.
 A.C. Grayling



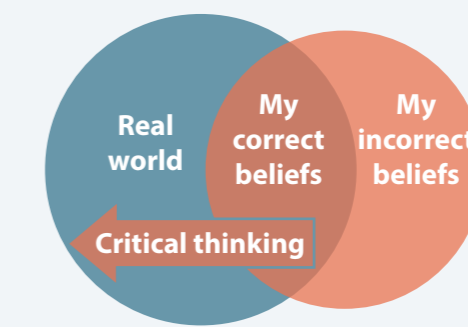
DEMARCATON CRITERIA

How to distinguish science from pseudoscience?

- Evidence** Empirical evidence is required.
- Correct reasoning** Be aware of formal and informal fallacies.
- Honesty** Strive for truth and honesty. Avoid and be aware of fraudulent practices.
- Ockham's razor** (law of parsimony) Do not postulate unnecessary entities. Proceed to simpler theories until simplicity can be traded for greater explanatory power competing hypotheses.
- Falsifiability** A theory has to be empirically falsifiable (Popper). E.g. 'Tomorrow it will rain in Utrecht' (falsifiable) vs 'Tomorrow it will rain, or not.' (unfalsifiable, always true).
- No anecdotal evidence** Anecdotes do not count as evidence.
- Clear concepts** A theory clarifies concepts. A theory should not use obscuring concepts e.g. the trinity, original sin, karma, chi, reincarnation, soul.
- Strange does not equal paranormal** Strange experiences are no evidence for the paranormal. (This is very counterintuitive!)
- Prediction** A theory should yield new knowledge and not explain or predict what is already known.
- Consistency of scientific disciplines** A new scientific theory should be compatible with other scientific disciplines.

What is critical thinking?

The best therapy against nonsense is critical intelligence.
 Paul Kurtz



Knowledge is the overlap between reality and what we think is real.
 We don't know everything. We might have incorrect beliefs about the world. We can strive towards more knowledge of the world and fewer incorrect beliefs about the world.

TOOLS OF CRITICAL THINKING

How can we think more critically?

Prerequisites

We need freedom of expression, scientific education and institutions, and liberal democracy.

Allround rationality

Critical thinking in all domains: question your most cherished beliefs.

Education

Curriculum which emphasizes scientific inquiry, literacy and numeracy.

Courage

Sapere aude: Dare to think.

Psychology

Understanding cognitive biases, limitations and dissonance.

Argumentation theory

Interdisciplinary study of how conclusions can be reached through logical reasoning.

Scepticism

Learn to distinguish science from pseudoscience. Turn on your baloney detector!

Train your brain

Make it a habit of your mind to always question knowledge claims. Brains need to work out.

Philosophy

The study of philosophy enhances problem-solving capacity and critical thinking skills. It helps one analyze concepts, definitions, arguments and problems. It contributes to the organization of ideas, assessments of value and the extraction of what is essential from masses of information. And it helps one to synthesize a variety of views or perspectives into a unified whole - like this chart.

Logic

An argument is sound if and only if it is valid *and* all its premisses are true. All sound arguments must necessarily have true conclusions. The problem is to figure out which arguments are sound and what premisses are true.

Numeracy

Ability to reason and to apply numerical concepts. A numerate person can manage and respond to the mathematical demands of life, including statistics and probability. Innumeracy can have a negative impact for example on risk perception towards health decisions.

Rhetoric

Be aware of the art of persuasion.

OBSTACLES TO CRITICAL THINKING

What are the obstacles to thinking critically?

Ignorance

In the age of information, ignorance is a choice. *It is wrong, always, everywhere, and for anyone, to believe anything upon insufficient evidence.* (W.K. Clifford)

Tradition

What people (including scientists) have been thinking throughout the ages, is no guarantee for truth. Most people most of the time have held false ideas.

Religion

Fear, tradition, ignorance and group pressure combined as institutionalized superstition.

Cognitive biases

Inherent thinking errors that humans make in processing information to accurately understand reality, even when confronted with all needed data and evidence. For example:

Cognitive dissonance

The tension that arises when one tries to combine incompatible beliefs, e.g. science and religion.

Credulity

Willingness to believe in the absence of reasonable proof.

Psychological limitations

The human brain is programmed for survival and reproduction. However, we can overcome these limitations and cognitive biases by critical thinking and science.

Teleological temptation

The human tendency that final causes exist in nature, meaning that design and purpose analogous to that found in human actions are inherent also in the rest of nature.

Fear

People can be afraid of knowledge because it may undermine cherished ideas and practices.

Confirmation bias

Tendency to only seek out information that conforms to their pre-existing viewpoints, and subsequently ignore information that goes against them. Avoiding confirmation bias is an important part of rationalism and in science in general.

Group pressure

Organized religion is an example of group pressure for accepting epistemological (and moral) dogmas. Truth is independent of what other people say.

Transcendental temptation

Magical thinking, the belief that people or events are 'magical' in that they have access to an unseen and hidden realm of power which lies behind our visible world but which can nevertheless be tapped into and used to affect our lives.

Dis- & misinformation

Disinformation is intentionally false or inaccurate information that is spread deliberately. It is an act of deception to convince someone of untruth. Misinformation is unintentionally false information.

SOME INFORMAL FALLACIES

How not to be deluded?

Ad hominem

Attacking the speaker instead of the arguments.

Falsum in uno, falsum in omnibus

(False in one thing, false in everything) When someone is found to be wrong about one thing, he or she is presumed to be wrong about everything.

Ad populum

(Bandwagon) Implying something is true, because many individuals say so.

Petito principii

(Begging the question) It is a statement that refers to itself to prove the assertion. *A is true because A is true.*

Ad antiquitatem

Implying something is true, because it's an old belief.

Post hoc, ergo propter hoc

Believing that temporal succession implies a causal relation. *It rained just before the car broke down. The rain caused the car to break down.*

Ad baculum

Threatening with violence or sanctions to make a point.

Ad Hitlerum

Implying something is wrong, because someone who does it has an association with evil. *Hitler was a vegetarian, therefore vegetarianism is wrong.*

Red herring

A clue which is intentionally or unintentionally misleading or distracting from the actual issue.

Non sequitur

(Fallacy of false cause) Incorrectly assuming one thing follow from another.

Straw man

Misinterpreting the opponent's position. Creating the illusion of having refuted a proposition by replacing it with a different position (straw man) and refuting the latter.