Lecture 9

A summary of scientific methods
Realism and Anti-realism

A summary of scientific methods and attitudes

What is a scientific approach?

This question can be answered in a lot of different ways. We will try to do it by describing three somewhat different areas where we use science.

- Scientific attitude in every-day situations.
- Scientific methods in smaller research projects.
- Science in big scientific theories.

Science in every-day situations

What does it mean to have a scientific attitude to things? Some suggestions:

- You are objective. Especially, you base your judgements on observations and verified facts.
- You realize to what extent you and everyone else can be biased by your/their perspective.
- You are curious and want to know facts.
- You have some knowledge of scientific methodology and try to apply it.

What scientific methodology?

Here are some scientific methods that also can be used in "simpler" situations:

- The HD-method for finding hypothesis. Use the formula H & A => E. (Lecture 3)
- Maximum Likelihood. Try to find H such that P(E | H) is maximal. (Lecture 6)
- If you are more advanced: Use Baye's formula for computing P(H | E). (Lecture 3)
- Realize that is A and B are correlated it doesn't have to mean that A is the cause of B. It can be the other way around, or neither. (Lecture 4)
- Use deduction. (Lecture 5)

Science in research projects

We identify three types of research projects:

- Exploratory research
- Testing-out research
- Problem-solving research

Exploratory research

- This is research on a new problem about which little is known.
- The problem may come from any part of the discipline; it may be a theoretical research puzzle or have an empirical basis.
- The research work will need to examine what theories and concepts are appropriate, developing new ones if necessary, and whether existing methodologies can be used.
- It obviously involves pushing out the frontiers of knowledge in the hope that something useful will be discovered.

Testing-out research

- In this type of research we are trying to find the limits of a previously proposed generalization.

- This is often termed the ‘null hypothesis', which we are bringing evidence to ‘overthrow’ - i.e. to show is inadequate.

- We can try to answer questions like: Does the theory apply at high temperatures? In new technology industries? With working-class parents? Before universal franchise was introduced?

- In this way we are able to make an original contribution and improve (by specifying, modifying, clarifying) the important generalizations in our discipline.

Problem-solving research

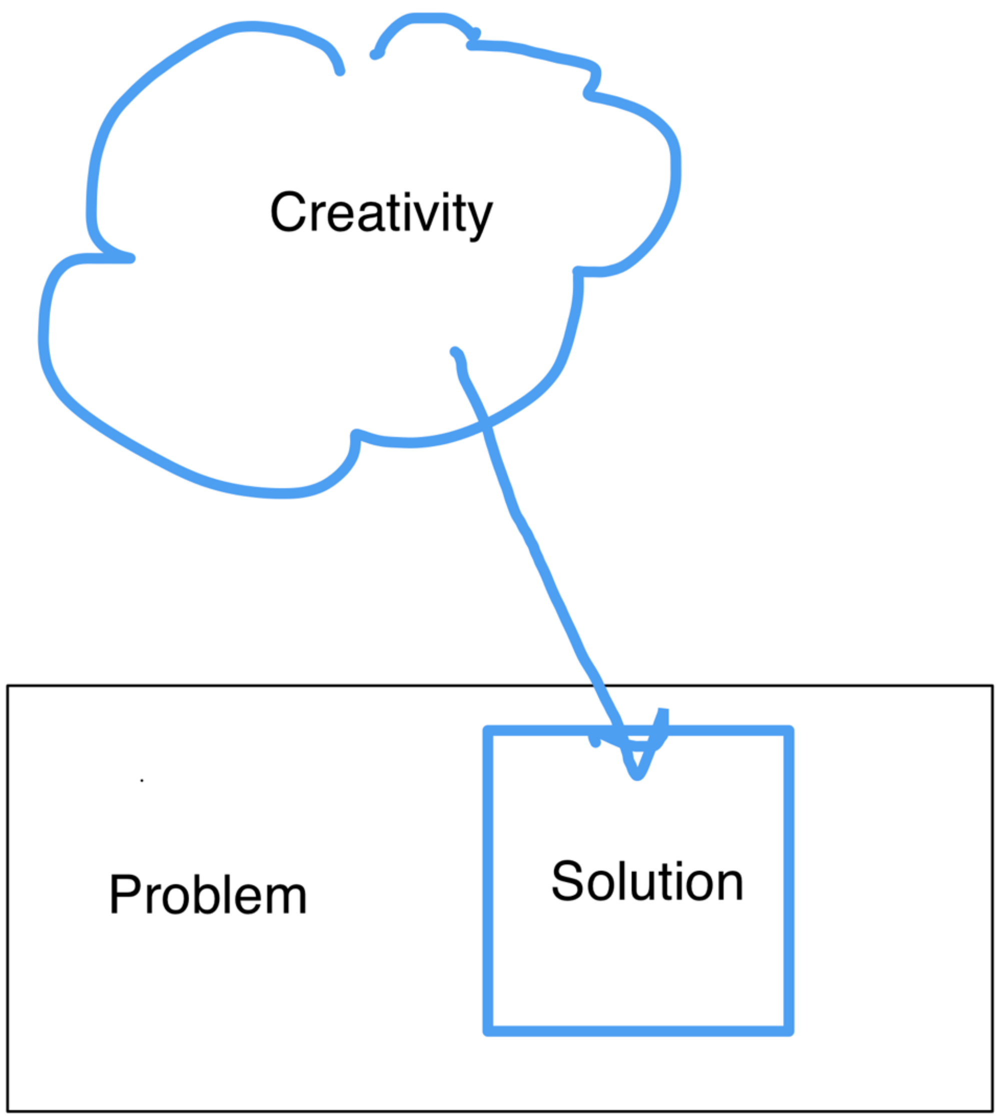
- In this type of research, we start from a particular problem in the real world, and bring together all the intellectual resources that can be brought to bear on its solution.

- The problem has to be defined and the method of solution has to be discovered.

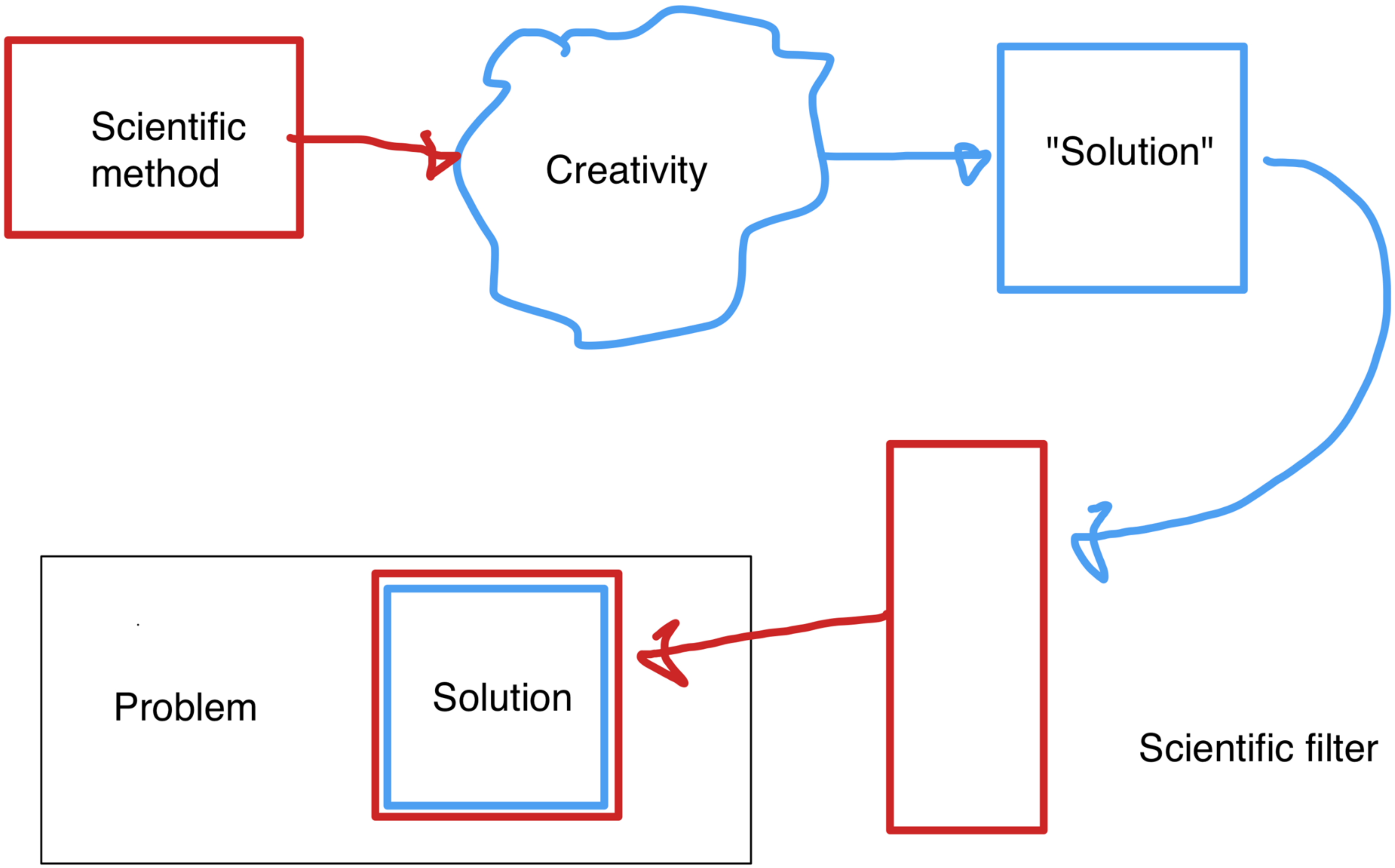
- The person working in this way may have to create and identify original problem solutions every step of the way. This will usually involve a variety of theories and methods, often ranging across more than one discipline since real-world problems are likely to be ‘messy’ and not soluble within the narrow confines of an academic discipline.

Science in an engineering project

The ordinary engineering process



The process with science "added"



What is the scientific filter?

1. We must put our solution in a broader scientific context. We must give references to other solutions and similar problems.
2. We must prove scientifically that our solution is *correct.*
3. We must put our solution in form of a report following scientific standards.

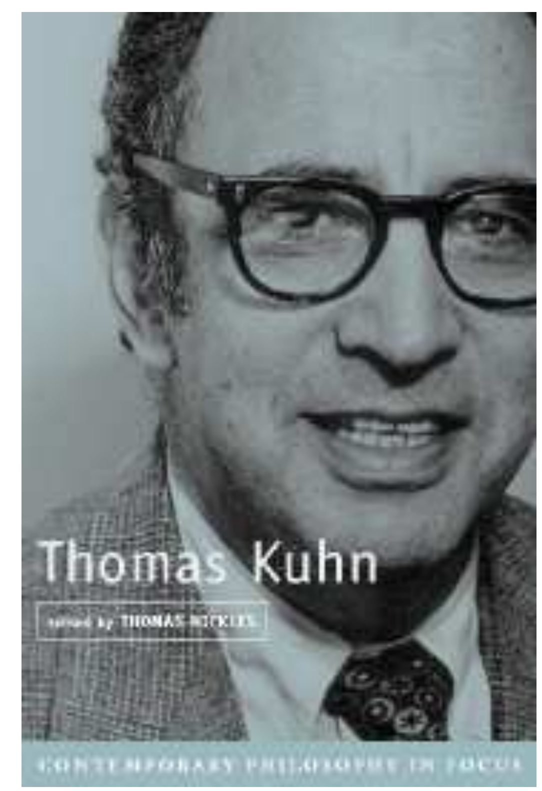
Scientific methods?

- In lecture 6 we described methods that can guide your creative process.
- We you prove that your solution is correct you can use deductive methods and/or statistical methods.
- To put problems in the right context you have to read (and know) a bit of science.

Big Science

Popper

- We have presented a short history of science.
- We have seen what Popper and Kuhn thought about science.
- Popper tried to characterize real science with his falsifiability-criterion.
- Kuhn described science by defining paradigms.
- Is there some other way to characterize scientific theories?



Judge Overton's charaterization

- He is known for his ruling on Act 590 "The Arkansas' Balanced Treatment Act" in McLean v. Arkansas, which was a law seeking to require the teaching of Creation Science in classrooms. This statute was advocated by its supporters as providing equal treatment of creation science as the Theory of Evolution in the science classrooms.
- When Judge Overton struck down the Act in 1982, he used the criteria that a scientific theory must be tentative and always subject to revision or abandonment in light of the facts that are inconsistent with, or falsify, the theory. A theory that is by its own terms dogmatic, absolutist and never subject to revision is not a scientific theory.

How to define a scientific theory

To be more specific, he used these five points to describe the difference between a scientific theory and a *pseudo-scientific* theory. A scientific theory must fulfill this:

- It is guided by natural law.
- It has to be explained by reference to natural law.
- It is testable against the empirical world.
- Its conclusions are tentative, i.e., are not necessarily the final word.
- It is falsifiable.

And what are the demands on a scientist?

1. At the most basic level it means that you have something to say that your peers want to listen to.

2. In order to do this you must have a command of what is happening in your subject so that you can evaluate the worth of what others are doing.

3. You must have the astuteness to discover where you can make a useful contribution.

4. You must be aware of the ethics of your profession and work within them.

5. You must have mastery of appropriate techniques that are currently being used, and also be aware of their limitations.

6. You must be able to communicate your results effectively in the professional arena.

7. All this must be carried out in an international context; your professional peer group is worldwide. You must be aware of what is being discovered, argued about, written and published by your academic community across the world.

Realism and Anti-realism

Science and Reality

Science ought to describe reality. But what is Reality?

Is what we think we see of reality really real?

If not, what are we then dealing with in science? Is it *representations* of reality?

Philosophical Terms

There are several different attitudes towards reality in philosophy:

- Naive Realism : Reality is more or less as we experience it.
- Critical Realism: Reality exists but we cannot experience it directly. There is, however, a close connection between reality and our experiences of it.
- Idealism: Reality does not exist. The only existing things are our (or just my) experiences.
- Phenomenalism: Reality exists but we can only know it through *constructions* based on observations made by our senses.

In Science

In Science there are two attitudes:

- Realism: The goal of science is to describe reality as it is.
- Anti-Realism: The goal of science is to describe the *observable* part of reality as it is.We cannot say anything about the non-observable part of reality.

What is not observable?

- We can say that electrons are not (directly) observable.
- In a way we can say that atoms are observable. But once they were not.
- Feelings are perhaps just possible to observe subjectively.
- Abstract concepts are not observable.

The anti-realistic attitude

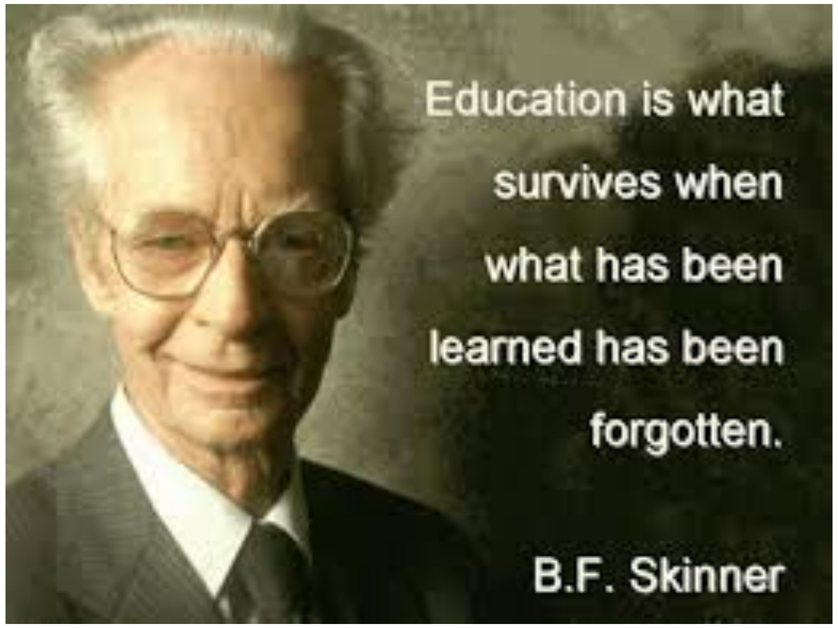
- Although the atoms in a sense, are observable, we should think about this example:
- Thermodynamic properties of gases can be explained by assuming that they are composed of atoms that move.
- According to anti-realists the existence of atoms is just a good fiction that helps us to explain the laws of thermodynamics.

Explanations of observations

- According to anti-realists is the core of science is the set of observable data.
- The purpose of the models is to explain these observable data.
- Anti-realism is also known as *instrumentalism*.

Behaviorism

- A special movement in psychology says that consciousness in a sense is a fiction.
- All scientific statements about consciousness must be based on observation.
- Consciousness is a fiction that describes these observations.
- This is a kind of *reductionism*.

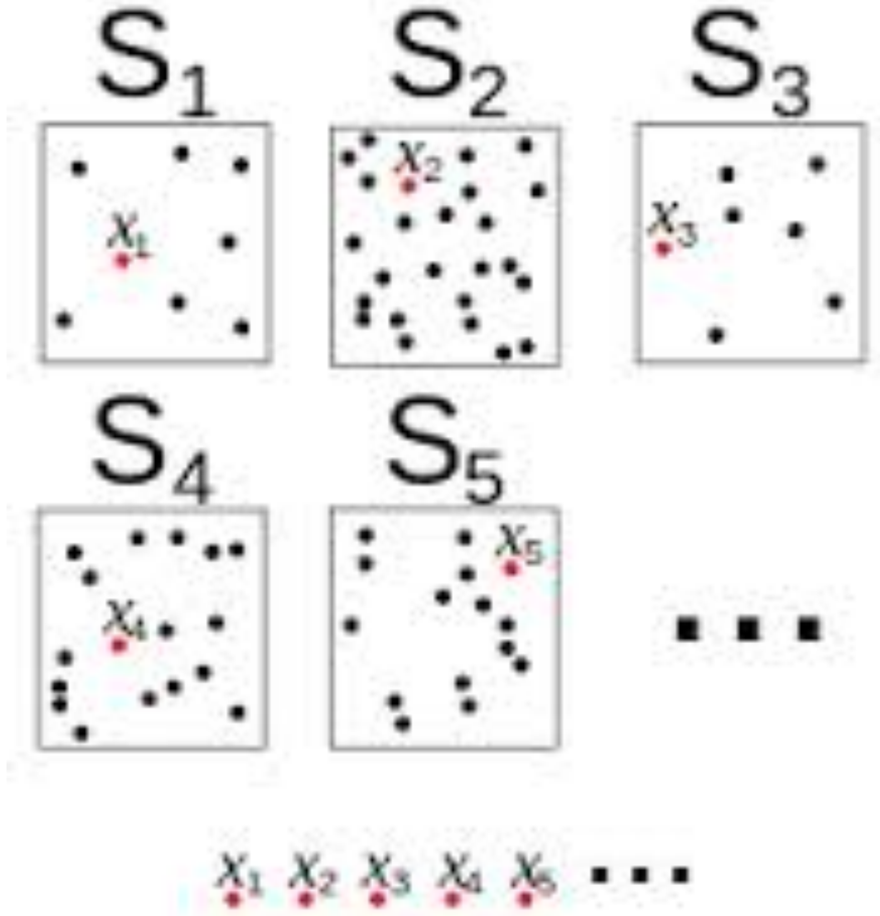


Fiction or not?

- There are actually two forms of anti-realism:
- We can say that theories, such as those concerning atoms, are pure fictions.
- We can say that theories, such as those concerning atoms, might be able to describe reality in a way. But we can never know if they are true. This approach is called agnosticism.
- The latter type of anti-realism is probably the most common.

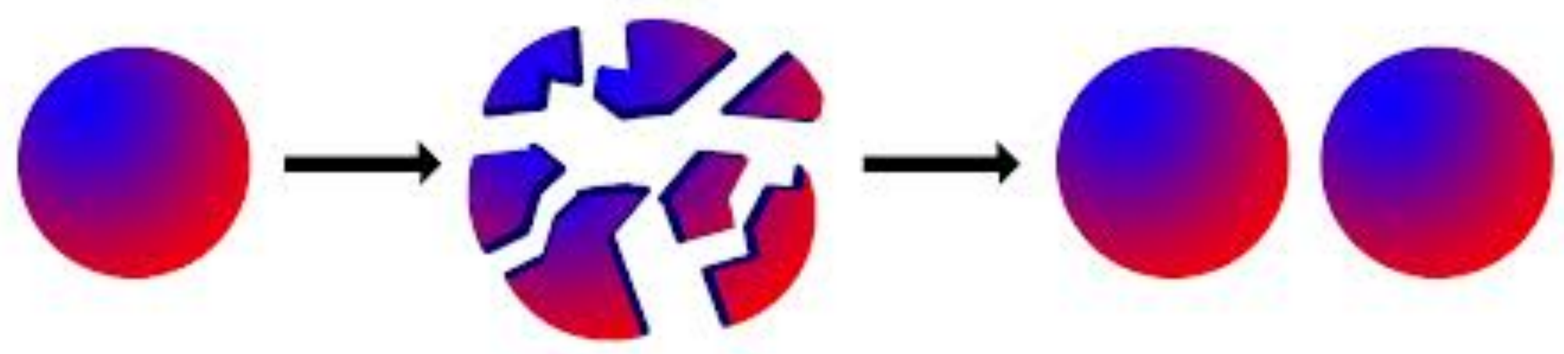
Realism in Mathematics

- The Axiom of choice says that if we have an arbitrary family of sets, we can choose an element from each set in the family.
- The selection is a function from the family of sets. The Axiom of choice says that this function always exists.
- The problem is that it doesn't have to be any explicit way of describing the function.



The status of The Axiom of Choice

- The axiom of choice is accepted by most mathematicians.
- It has many useful and important consequences.
- However, it has some strange consequences such as The Banach-Tarski Paradox.
- The paradox says that it is possible to divide a sphere with volume 1 into a number of parts and put the parts together and form two spheres which both have volume 1!
- The paradox "works" because we can it divide the sphere into parts that do not have measurable volumes.



Is the axiom contradictory?

- There are axiom schemes like The Zermelo–Fraenkel Set system (ZF) that seems to describe the basic math correctly.
- Gödel showed that the axiom of choice can be added to ZF without contradiction.
- Cohen showed that the negation of the axiom of choice can be added to ZF without contradiction.
- The conclusion is that using ZF we can neither prove or disprove the axiom of choice.

What do we do then?

- There are at least three approaches:
- We can believe that there is an objective answer to the question about the axiom of choice is true or not. We must try to understand the mathematical reality better. This approach is called realism.
- We choose to only deal with such mathematics can be proved constructively. We cannot know if The axiom of choice is true. This approach is known as constructivism.
- We can choose to accept the axiom of choice as true or false, depending on what we want. Have it your way! This approach is called formalism.

More details

- Realism: there is a mathematical reality that exists independently of us. Mathematicians are exploring this reality. Also called Platonism.
- Constructivism: the mathematics are designed by us. Only what is constructed or potentially possible to construct is real. This view (or a variant of it) is also known as Intuitionism.
- Formalism: Mathematics is just a sort of game with symbols. Mathematicians examine the consequences of the different rules of the game. Everything that does not lead to a contradiction is allowed. This view is a form of anti-realism.

Strength and weakness of anti-realism

- Gives a certain intellectual sanitation.
- Is quite natural. The reality can never be exactly what we imagine it to be.
- At the same time, it seems that an anti-realist position can limit our ability to speak about things.

Realism vs. anti-realism

- A summary of the positions:
- Realists believe that science is an accurate description of reality, even those parts of it that cannot be observed directly.
- Anti-realists believe that science can only describe the observable parts of reality and that the theories often are only fictions or models about which we cannot say that they are true or false.
- What are the reasons for the different positions?

The "No miracles" – Argument

- This is an argument for realism.
- There are scientific theories that manages to describe the observable part of the reality very well.
- They do so by describing a model for a non-observable reality and explain how this is projecting on the observable reality.
- How do you explain the "miracle" that this description of the non-observable reality works so well?
- No miracle! It works because it is true!

Counter-arguments

- In the history of science, there are many examples of theories that explains observable data very well but still proved to be incorrect.
- One such example is The Phlogistone Theory. (It was observable data that ultimately led to the rejection.)
- A critical example is theories of light nature.

The argument from observability

- This is also an argument against anti-realism.
- Anti-realism is based on the supposed fact that we can divide the world into observable and non observable parts.
- But can we really do that in a consistent way?
- There are, for example. a gradual transition from observability with the eye to observability with electron microscopes. It is the first one a genuine observability but not the other one?

Counter-arguments

- That type of argument really just shows that observability is a vague concept. It does not necessarily mean that it is a meaningless concept.
- We can see that there are clear cases of what is observable and clear cases of things that are not. That's enough for anti-realism.

The argument from under-determination

- This is an argument for anti-realism.
- We imagine that we have a set of observed data. We want to find a theory that explains the data.
- It is possible to realize that there is always a variety of theories that may explain these data. The theories are being under-determined.
- If you are using a theory to explain the data, it is just an arbitrary tool for the explanation.
- That's exactly what anti-realists believe about theories.

Counter-arguments

- Although there are different theories that could explain the measured data, they are not all equivalent.
- It seems natural that there is some kind of selection criterion, for example, choosing the simplest theory.
- It also seems to be a lack of historically interesting examples of under-determination.

Laws

- What is a scientific law?
- It seems natural to interpret it as a regularity in nature.
- But there is a problem: The law of gravity specifies a rule for how bodies fall. It is not literarily true, however, due to air resistance. How can it then be a law?
- Laws should perhaps be interpreted as a tendency? They strike through, depending on strength.

The mystery of laws

- Why does nature follow laws?
- Does it do that?
- Newton's laws seems to be very successful.
- But is not the concept of force just *defined* in a way that makes it work?
- We may just see the laws that work?

Computer Science

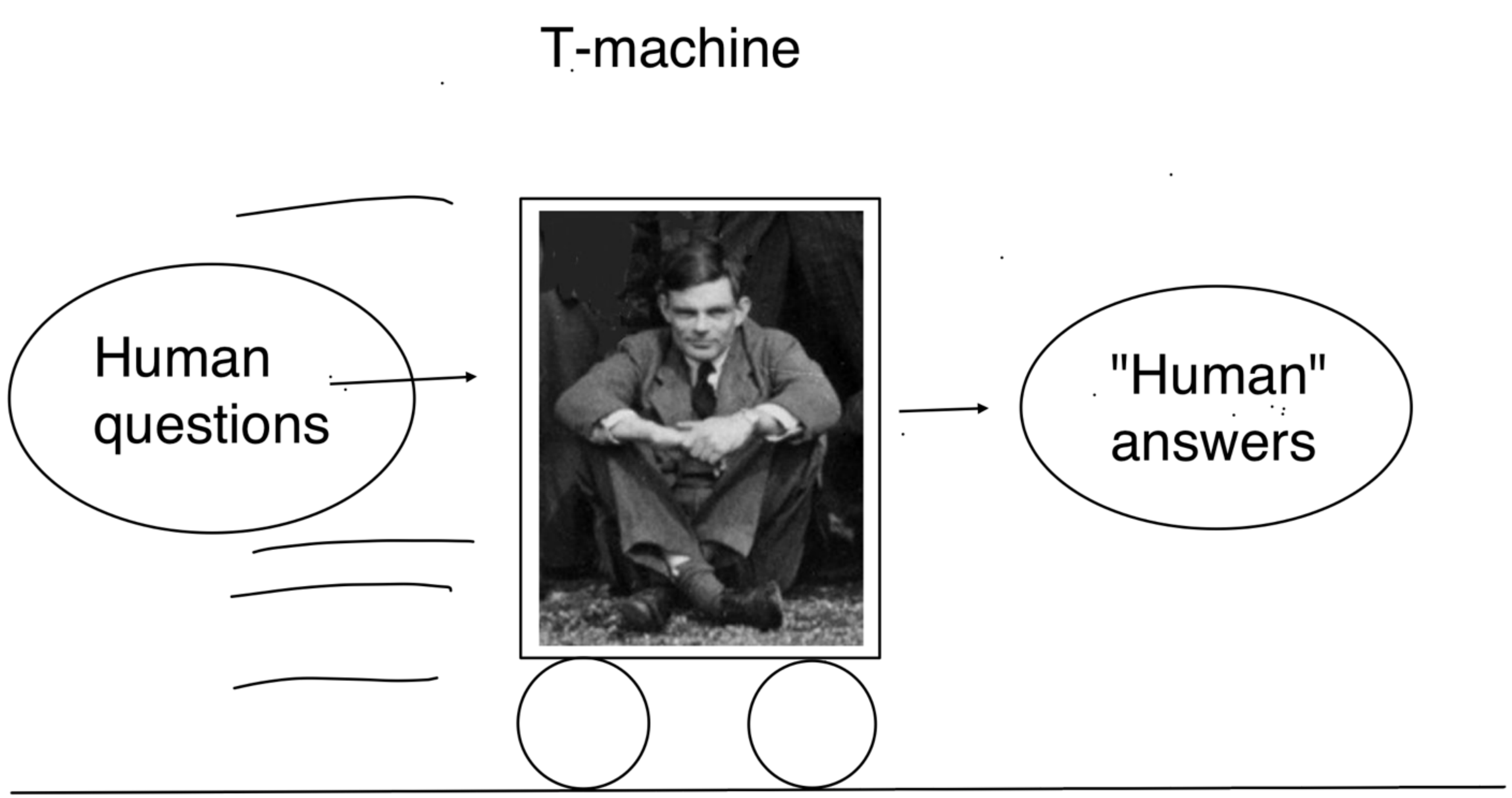
- What are the Computer Science problems relating to realism and anti-realism?
- The problems seems to be the same as in mathematics. But computer science works primarily with discrete mathematics that usually use finite methods. (Not so much of ontological problems.)
- Does the NP-question have to be decidable?
- Maybe the problem of consciousness is an example of the realism / anti-realism character?

The Turing Test

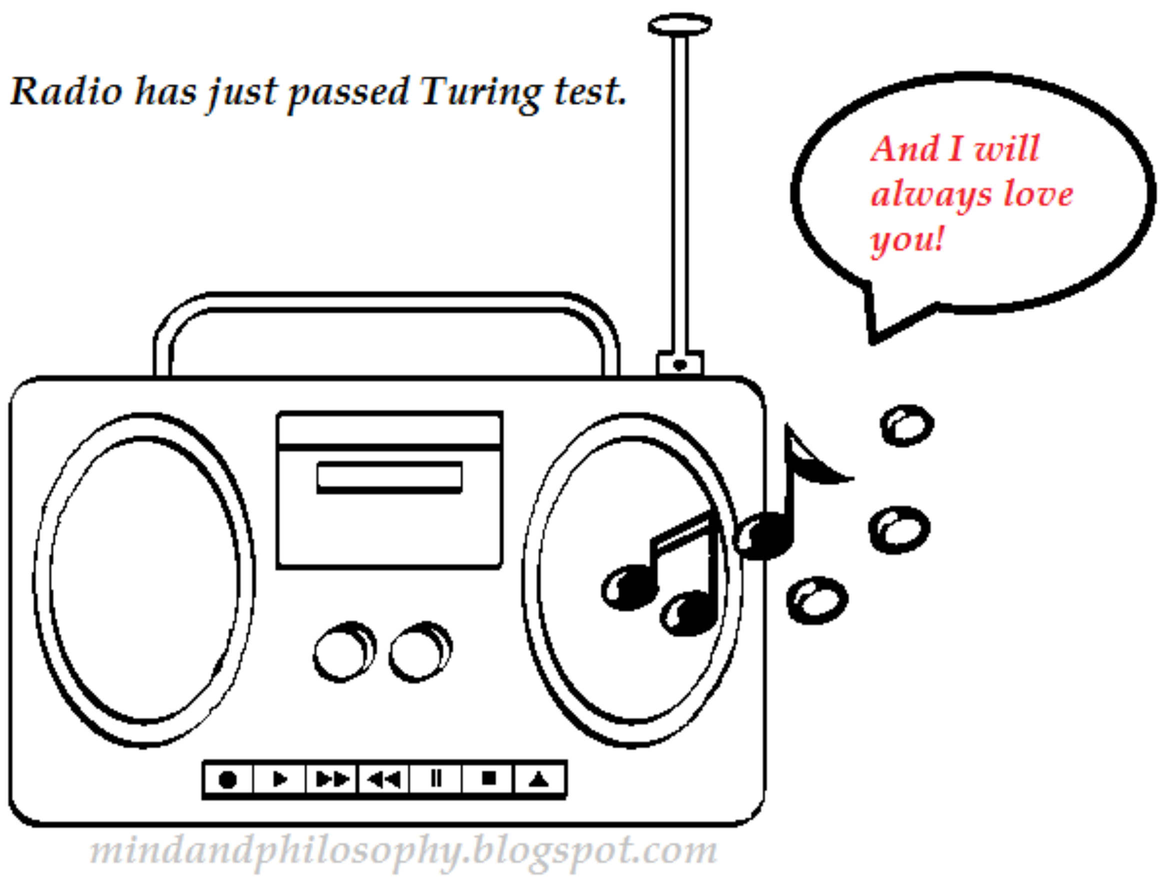
A machine passes the Turing test if it convinces you that it is human.

In that case:

- Is it "like" a human?
- Is it equivalent to a human?
- Is it human?



What is human consciousness?



- Can a computer have feelings and consciousness?
- In the same way as humans have?
- Can a computer be you?
- Are you a computer?
- Perhaps consciousness is a convenient fiction?
- Many people think these are interesting and disturbing questions.
- And they are scientific questions (or?)