Lecture 2

Induction and the HD Method

Logic and Experiments

- In the beginning science was all about logical reasoning. Scientists/philosophers tried to find theories about nature.
- What is a theory? In logic a theory is a set of axioms and all consequences following from them by deductions.
- The foremost demand on a theory is that it is *consistent,* i.e. that no contradictions follow from it.
- But then we have the demand that the theory should describe reality correctly. We must confront the theory with experiments. (Or must we?)

The idea of Empiricism

- Logical Positivism aka. Logical Empiricism is a philosophy of science that was particularly influential in the first half of the 20th century.
- One of the principles of LP is demands we must put on a statement S in order for it to be *meaningful.*
- Let S be any statement put in a form that indicates that it should be true or false. It is meaningful if either:
- it in principle can be proved or disproved using logical methods
- there are some observations that would confirm or disconfirm the statement
- All other statements are *meaningless.*
- It is now generally thought that this demand is too strong, but it is still a good guiding principle.

The connection between theories and observations

- We will spend some time on analyzing the positivistic theories and some questions related to them.
- Can we use observations and form a theory from them?
- Can we first form theory and then check it against observations?
- First we shall study the famous induction method.

Induction

- The basic idea: We make observations and try to see a pattern in them.
- If the observations are many and all agree with the pattern we conjecture that the pattern always applies.
- There are at least two different standardized forms of the method.

Induction: A basic form

- We make observations of objects which all has property A.
- Let us assume that in all observations the objects also have property B.
- We conclude that all objects with property A also have property B.

Does induction work?

- Yes, basically. There are however counter-examples.
- The set of observations most be chosen in a sufficiently general way.
- What is the logical basis for induction?
- One motivation for induction is the weak principle Uniformity of Nature (UN), see Okasha ch. 2.

A critic

David Hume 1711-1776

There is no scientific ground for induction!

- Induction cannot be proved to be correct using logic.
- Induction cannot be proved using induction (circular reasoning).
- We believe in induction since it seems to work.
- But it cannot be used for scientific proofs.

A solution?

Karl Popper 1902-1994

- Popper claims that he has solved the riddle of induction.
- The solution is that we never really use induction!
- We can never verify hypothesis.
- We can only falsify them.

Can induction generate theories?

- The idea is that we can see patterns and we can generalize them into theories.
- By using the induction principle we can "prove" the theory.
- But can it be done? There are at least three objections.
- The fact (if it is a fact) that we must first have a theory before we can make observations.
- Underdetermination.
- Goodman's paradox.

Observations depend on theories and expectations

- ”We see what we believe”.
- Rosenthal's experiment: A group of medicine students was divided in two groups. They were supposed to make an intelligence test on mice. They are each given a set of mice.
- Group A is told that their mice are the most intelligent. Group B didn't get to know anything.
- Group A found that their mice performed better in the test than the mice in the other group.
- But A and B were given mice of the same type!
- It seems as if the expectations in group A influence the result.
- For reasons like this it is recommended that one should perform double blind tests.

Underdetermination

- To each set of observations there are always different theories that fits the data.
- Perhaps we should chose the simplest theory (Occam's razor). But will that always give the best result.
- Goodman's paradox: Let us say that a thing is *grue* if it either is green and has been observed before Christmas Eve 2013 or has not been observed before Christmas Eve 2013 and is blue.
- Induction seems to tell us that that all emeralds are grue. Is that true?

In spite of this ...

- It seems as if it is impossible not to use induction, at least in everyday situations
- But what should we do in science?
- We will describe a method that is a sort of development of the induction method.

Some history

We will now study the history of the *first scientific revolution* (as it is often called).

It is the history of how we changed from the *Geocentric* view of the world (Earth in center of the universe) the the *Heliocentric* view (Sun in center of the universe).

The first revolution

Copernicus

The Renaissance

During the Renaissance several scientific developments took place.

- The human body and the circulation of the blood
- Copernicus' heliocentrical worldview

The heliocentrical worldview

Kepler

The heliocentrical worldview

- Tycho Brahe makes observations. He describes his own worldview: The Earth is at the center of the Universe. The Sun orbits the Earth. The planets orbit the Sun.
- Kepler describes a new heliocentrical worldview where the planets move in ellipses.

The scientific revolution

Galilei

Descartes

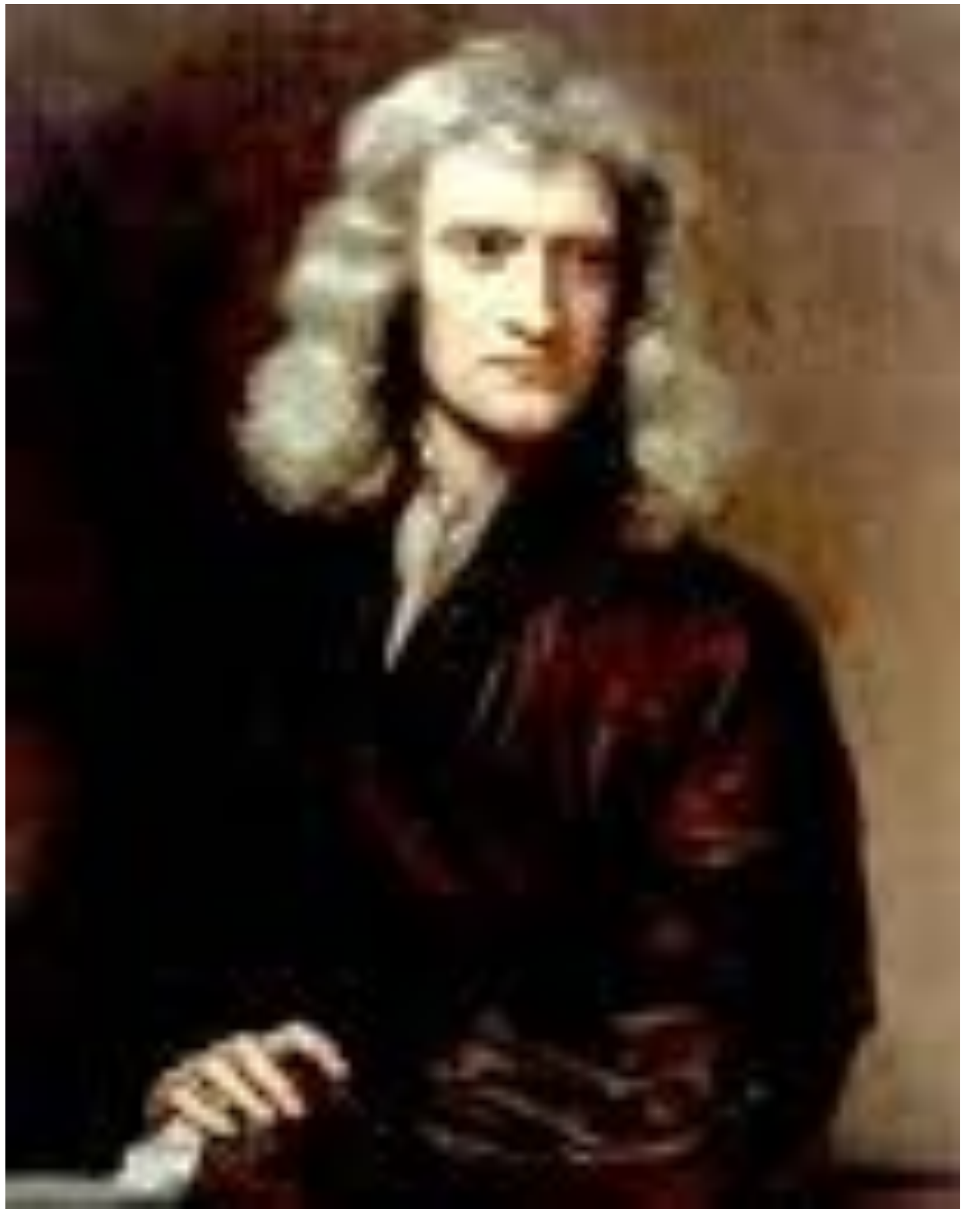
The scientific revolution

- Galileo Galilei makes experiments.
- He discovers a law for the movements of pendulums.
- Bodies with different weights fall equally fast.
- He constructs telescopes. He discovers mountains on the surface of the moon.
- and moons circling around Jupiter.
- and rings around Saturn.
- He becomes convinced by Copernicus' model.
- He gets punished by the church.

The scientific revolution II

- Descartes: ”Cogito, ergo sum" (I think, therefore I am)
- He creates a program for how research should be done.
- He presents a totally mechanistic worldview: Everything can be explained by interactions between physical bodies.
- He invents analytical geometry.

Newton's mechanics



Newton

Newton's mechanics

- At the age of 23 Newton formulates three mechanical laws and the law of gravitation.
- He develops the Calculus (Differential-and Integral Calculus).
- The calculus and his mechanics form the cornerstone in the first modern science.
- At the end of the 17th century Newton's mechanics is internationally recognized.
- Newton is perhaps the first really socially esteemed scientist.

Science established

- The Royal Society is established in England.
- Experiments are performed.
- Research on astronomy, gases and animals. Microscopes are used.
- Newton is at several times in conflict with the other scientists.
- Newton's optics.
- Conflict with Leibniz.

The two methods of science

- In science we work both with deductions and observations.
- In mathematics it is almost always deductions.
- In physics we work with both methods.
- In social sciences and humanities the situation is more uncertain. But in a way observations must be used.

Is there a general scientific method?

- Science has at least four different components:
- To set up hypotheses.
- To verify the hypotheses with logic.
- To evaluate the hypotheses by doing observations.
- To do experiments that generate observations.

Is there a general scientific method?

- A suggestion: It could be the Hypothetico- Deductive Method.
- It is certainly used in physics and chemistry.
- In a specialized sense it is used in mathematics.
- It seems as if it used sometimes in Social Sciences.

Carl Hempel 1905-1997

The general method

- A general method for handling observations is the Hypothetico-Deductive Method (The HD Method).
- The HD Method and the way of thinking connected to it is a central theme in scientific thinking.
- But not all researchers agree.
- Physics, astronomy, chemistry and biology seem to be the most natural areas for the method.

How it works

- Let us assume that we have a hypothesis H. We want to know if it is true or not.
- H can be a single fact or a general law.
- We have different observations E1, E2, …, En.
- (The observations can be generated by an experiment. They can also exist before H.)
- Does the observation *confirm* or *disconfirm* the hypothesis H?
- The HD Method is a way to find an answer to that question.

A special case: Induction

- Goodman's problem: What hypothesis is supported by the induction?
- We first decide which hypothesis we want to test. (Goodman's problem doesn't occur.).
- A common form: H says that "All objects of type has property B".
- The observations are of the type: E1 = "Object O1 that is of type A has property B", and so on.

The HD Method used for falsification

- We have a hypothesis and want to show that it is false.
- We have a set of observations E1, E2, …, En.
- Assume that there is an observation Ei such that H => not Ei.
- Then Ei falsifies H.

Chemistry

Scheele

Lavoisier

Chemistry

- Great steps are taken in the 18th century.
- At the beginning of the century almost nothing is known about atoms and chemical elements. There are only two known gases: Air and carbon dioxid.
- Oxygen is discovered. (Scheele/Priestley).
- Hydrogen is discovered (Cavendish). Man It is discovered that water is composed of hydrogen and oxygen.
- Lavoisier disproves the so called phlogiston theory of combustion.

Chemistry II

- John Dalton discovers the atom.
- Berzelius describes the composition of elements.
- He creates the modern chemical notation for substances.
- Mendeleyev creates the periodic table.

The Phlogiston Theory

Antoine Lavoisier

The Phlogiston Theory: When an object is burning it is phlogiston leaving the object.

The Phlogiston Theory was falsified by Lavoisier.

The falsification of The Phlogiston Theory

- Let H be The Phlogiston Theory.
- A consequence of The Phlogiston Theory must be that burning objects get lighter.
- But we can find certain metals that get heavier after burning. Let us call this observation E.
- Since H => not E, we have falsified H.