Theories and Methods of Research

Winter Semester 2015/2016
Lecture #1 (Oct. 19, 2015)

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This course (1)

What do you expect this course to be about?

What do you think you can learn here?

This course (2)

Course contents:

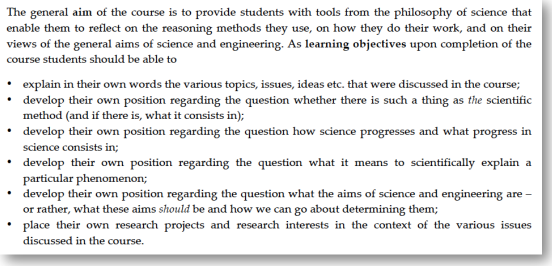
- Practice-oriented introduction to philosophy of science for engineering and practice-oriented science students
- How does science work?
- How is science able to produce reliable knowledge?
- Some elements of good scientific practice

Why would this be of interest to you?

- You should be able to do a good job as a researcher / engineer
- This does not so much involve doing what you've been taught in the lab as it involves thinking for yourself about the aims, methods, and context of your work
- First of all: what does it mean to do a good job?
  - Depends on what you might think the aim of your work is
  - This aim is set by you, society, your institute, …

This course (3)

Course aims:



The general **aim** of the course is to provide students with tools from the philosophy of science that enable them to reflect on the reasoning methods they use, on how they do their work, and on their views of the general aims of science and engineering. As **learning objectives** upon completion of the course students should be able to

- explain in their own words the various topics, issues, ideas etc. that were discussed in the course;
- develop their own position regarding the question whether there is such a thing as *the* scientific method (and if there is, what it consists in);
- develop their own position regarding the question how science progresses and what progress in science consists in;
- develop their own position regarding the question what it means to scientifically explain a particular phenomenon;
- develop their own position regarding the question what the aims of science and engineering are – or rather, what these aims *should* be and how we can go about determining them;
- place their own research projects and research interests in the context of the various issues discussed in the course.

This course (4)

Audience (compulsory, 2nd year of study):

- M.Sc. International Horticulture (3 CP)
- M.Sc. Water Resources and Environmental Management (3 CP)

Also intended for:

- M.A. Philosophy of Science (5 CP)
- M.Ed. Philosophy (5 CP)
- B.A. Philosophy (advanced students, research focus, 6 CP)

Session structure:

- Lecture (about 70 min.)
- Discussion on questions prepared by the participants:
  - Things you didn't understand from the lecture
  - Things you didn't understand from the readings
  - Things you found controversial

This course (5)

Requirements for passing this course (IntHort & WatEnv only!):

1. Prepare all required readings in advance of the class & write down a few questions / topics for discussion
2. Participate actively in class
3. Give one oral presentation (IntHort) or hand in one written discussion (WatEnv) on your research, connecting it to some of the the course topics
4. Pass a written exam at the end of the course

Grading:

- M.Sc. International Horticulture (3 CP): Presentation in class: 20%, written exam: 80%
- M.Sc. Water Resources and Environmental Management (3 CP): Witten presentation in class: 20%, written exam: 80%

This course (6)

Presentation in class (IntHort, 20% of grade):

- Three sessions available, 15-min. time slots per person (6 presentations per session)
- Present (1) your research, (2) the aims of your work, (3) your views about how your work connects to the main issues in the lectures, (4) your views about how this could help your work
- Note: "not at all" is a possibility regarding (4) too!

Written discussion (WatEnv, 20% of grade):

- Basically the same as the oral presentation, but in writing (3 pp.)

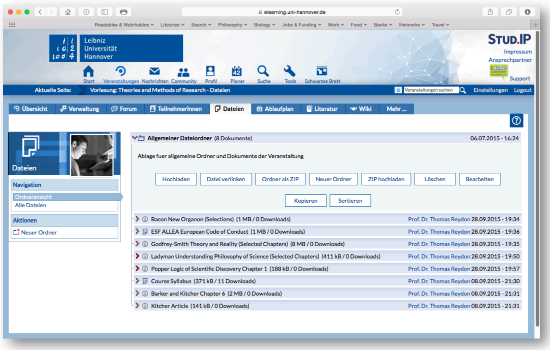
Written exam (80%):

- Six short questions about the main topics of the lectures
- You have to answer five (2 points per answer, total 10 points)
- You are free to select which five you answer

Office hours, contact, essential infos

Office hours:	Tuesdays, 16-18h (without appointment) Bldg. 1146, Im Moore 21, Room B 421 (one floor up from the lecture room)
Email:	reydon@ww.uni-hannover.de (I usually answer emails within 24 hours)
Phone:	Do not call me!
Note:	Everything you need to know about the course should be in the syllabus. So: always first check the syllabus, the course website, etc. before asking me!
Note:	Earlier versions of this course were given by other instructors, and you might find the lectures on YouTube, iTunes, etc. This edition of the course to some extent parallels earlier versions – but only to some extent.

Readings



Aktuelle Seite: Vorlesung: Theories and Methods of Research - Dateien

Allgemeiner Dateiordner (8 Dokumente) 06.07.2015 - 16:24

Ablage fuer allgemeine Ordner und Dokumente der Veranstaltung

Bacon New Organon (Selections) (1 MB / 0 Downloads)	Prof. Dr. Thomas Reydon	28.09.2015 - 19:34
ESF ALLEA European Code of Conduct (1 MB / 0 Downloads)	Prof. Dr. Thomas Reydon	28.09.2015 - 19:36
Godfrey-Smith Theory and Reality (Selected Chapters) (8 MB / 0 Downloads)	Prof. Dr. Thomas Reydon	28.09.2015 - 19:35
Ladyman Understanding Philosophy of Science (Selected Chapters) (411 kB / 0 Downloads)	Prof. Dr. Thomas Reydon	28.09.2015 - 19:50
Popper Logic of Scientific Discovery Chapter 1 (188 kB / 0 Downloads)	Prof. Dr. Thomas Reydon	28.09.2015 - 19:57
Course Syllabus (371 kB / 11 Downloads)	Prof. Dr. Thomas Reydon	08.09.2015 - 21:30
Barker and Kitcher Chapter 6 (2 MB / 0 Downloads)	Prof. Dr. Thomas Reydon	08.09.2015 - 21:31
Kitcher Article (141 kB / 0 Downloads)	Prof. Dr. Thomas Reydon	08.09.2015 - 21:31

Sessions (1)

1. (19.10.15) Introduction: What is philosophy of science?
2. (26.10.15) The origins of modern science, inductivism as scientific method, Francis Bacon
3. (02.11.15) Inductivism
4. (09.11.15) Inductivism (problems)
5. (16.11.15) Falsificationism
6. (23.11.15) Falsificationism
7. (30.11.15) Revolutions and research programs
8. (07.12.15) Explanations and laws of nature
9. (14.12.15) Values, aims and good science (ethical issues, good scientific practice)
10. (21.12.15) Values, aims and good science

Sessions (2)

(28.12.15) No class: Christmas break

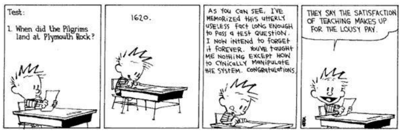
(04.01.16) No class: Christmas break

11. (11.01.16) Student presentations (IntHort)
Written assignments due (Wat Env)

12. (18.01.16) Student presentations (IntHort)

13. (25.01.16) Student presentations (IntHort)

14. (01.02.16) Written exam



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Theories and methods of research?

You may wonder about the course title:

- What is meant by 'theories of research'?
- Theories (philosophical ones, not scientific ones) about how scientific research works in practice – and perhaps also about how it could work better
- This is a look at science (and engineering) from the outside!
- Research methods: not how to perform PCR, how to setup particular experiments, how to do field work, how to apply knowledge to real-life problems, etc.
- Rather: methods of reasoning, of making inferences (from observations & data to general claims & theories, to establish theories, to test & confirm theories, to make claims about particular cases, etc.)
- So: you're not going to learn how to do research, you're going to learn to think about how you reason, how you do your work

What is philosophy of science? (1)

Core questions:

- What *is* science? How can science be characterized?
- Demarcation: What distinguishes science from other endeavors? (non-science, pseudo-science)
- How does science succeed in producing reliable knowledge?
- When is a phenomenon explained scientifically? How do scientific explanations work? What makes a good explanation?
- What distinguishes scientific knowledge from everyday knowledge?
- When is scientific knowledge reliable? How are theories and other claims confirmed? How does evidence support claims? What does it mean to say that findings are scientifically proven?

A common answer: the scientific method(s) distinguishes science from the rest, is used to prove claims, yields reliable knowledge, …

What is philosophy of science? (2)

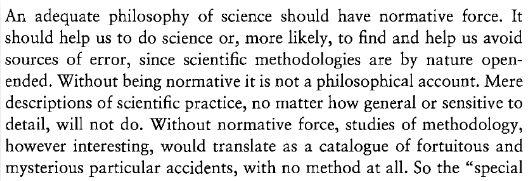
Areas of work:

- Methodology
- Epistemology
- Metaphysics
- Philosophies of particular sciences: philosophy of physics, of biology, of social science, of economics, etc.
- Ethics of science: is this part of philosophy of science? (I think it is, but not everyone agrees – cf. Ladyman's text)
- Science policy, issues in science & society (E.g., what are the responsibilities of scientists or engineers as / in the role of scientists or engineers)
- Sociology of science?
- History of science? (New trend: &HPS)
- Overlap with theoretical science (phil. bio. / theoretical biology)

What is philosophy of science? (3)

Aims:

- To understand / describe how science works
- To improve science? (I we better understand what we're doing, we might do it in a better way)



An adequate philosophy of science should have normative force. It should help us to do science or, more likely, to find and help us avoid sources of error, since scientific methodologies are by nature open-ended. Without being normative it is not a philosophical account. Mere descriptions of scientific practice, no matter how general or sensitive to detail, will not do. Without normative force, studies of methodology, however interesting, would translate as a catalogue of fortuitous and mysterious particular accidents, with no method at all. So the "special

(Wimsatt, 2007: 26)

Epistemology (1)

The theory of knowledge:

- What is knowledge? When do we speak of knowledge as opposed to – for example – mere belief?
- Under what conditions can I say that I know something? (I know the Earth orbits around the sun – but on what basis do I know this? School, reading, TV, trust in science, …)

The standard definition (which has its problems):

- Knowledge is (1) justified (2) true (3) belief
- Belief? A matter for psychology
- Truth? Oh dear … (Can we say that our best theories are true? How do we know?)
- Justification? There's everyday justification and there's justification in science. Scientific knowledge is justified in a special way – so, what's so special about science?

Epistemology (2)

Aims of epistemology:

- Achieving clarity on what knowledge is, what it consists in, what criteria apply for considering a claim to be knowledge
- Evaluating the methods of obtaining knowledge – how do the methods we actually use work, (how) could we devise better methods?
- Refuting skeptical claims: "We don't really know anything about the world, we're caught in our fallible beliefs!"

Some reasons for skepticism:

- There are no good ways to justify our beliefs, therefore they are mere beliefs, not knowledge
- Observation is limited by the nature of our senses
- Observation is theory-laden – you cannot "just look" (You need categories & concepts to recognize what you see)

Metaphysics (1)

The theory of what there is:

- Science tells us what there is in the world: electrons, fields, forces, atoms, genes, species, societies, …
- How are we to conceive of these things? E.g., what exactly is a gene? If you look at an organism's DNA, you don't see genes! (Genes are identified on theoretical grounds, so they depend on your perspective)

Realism and instrumentalism (Ladyman, p. 17):

- Two different stances with respect to what science tells us about the world, expectations of what science can deliver
- The realist believes that there really are electrons, etc. in the way science describes them
- The instrumentalist doesn't really care, as long as the theories, formulas, etc. adequately describe the phenomena

Metaphysics (2)

Why metaphysics doesn't go away:

- It seems that explanations and predictions of phenomena have to connect to what the world is like
- For example: laws of nature, causal powers of things
- So it seems we need an account of what kinds of things there are, what causal powers they have, and how they interact with other things (as described/governed by laws of nature) – explanations have to end somewhere

But also:

- Need for more clarity about core scientific concepts (space, time, force, field, particle, …)
- Need to clarify what is meant by specific concepts (such as 'gene', 'species', …) & to interpret scientific theories
- Science influences our worldview!

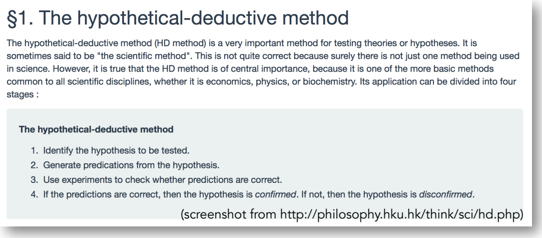
Logical Positivism (later: Logical Empiricism)

- Where what we today know as philosophy of science began (early 20th century)
- But philosophers in ancient Greece already did philosophy of science, even though there was no science in the modern sense
- Physics as the role model for science (laws of nature, mathematization, strictness of reasoning)
- Aims:
  - to describe the logical structure of scientific reasoning
  - To explain how evidence can confirm theories
  - To do this in the form of a logical account in the form of abstract relations between sentences (→ induction)
- Note: it's not about how theories can be proven, but about how they can be supported by evidence
- Empiricism: evidence derives from observation, which always is of individual cases (again → induction)

Hypothetico-Deductivism

The basic idea: a theory is confirmed when it entails a consequence that turns out to be true; the more such consequences, the more confirmation we have

This is still often presented as the core of science:



§1. The hypothetical-deductive method

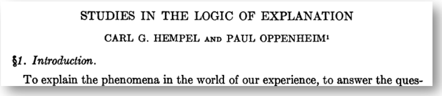
The hypothetical-deductive method (HD method) is a very important method for testing theories or hypotheses. It is sometimes said to be "the scientific method". This is not quite correct because surely there is not just one method being used in science. However, it is true that the HD method is of central importance, because it is one of the more basic methods common to all scientific disciplines, whether it is economics, physics, or biochemistry. Its application can be divided into four stages :

The hypothetical-deductive method

1. Identify the hypothesis to be tested.
2. Generate predications from the hypothesis.
3. Use experiments to check whether predictions are correct.
4. If the predictions are correct, then the hypothesis is *confirmed*. If not, then the hypothesis is *disconfirmed*.

(screenshot from http://philosophy.hku.hk/think/sci/hd.php)

Some later history of philosophy of science



STUDIES IN THE LOGIC OF EXPLANATION

CARL G. HEMPEL AND PAUL OPPENHEIM[1]

§1. Introduction.

To explain the phenomena in the world of our experience, to answer the ques-

Turn to episodes in the history of science (1950s)

- Actual science doesn't work in the strict, neat logical way shown by Logical Positivism/Empiricism
- Actual science is more complex, less ordered
- Thomas Kuhn (1962): revolutions in the history of science (radical breaks with previous ways of thinking)
- Paul Feyerabend: there is no scientific method

Turn to science as it is done today, looking at practice

- Development of the philosophies of the special sciences: Philosophy of Physics, of Biology, of Social Science, etc.

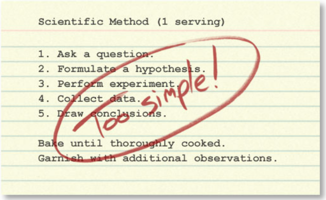
The structure of this lecture course

Sample two famous candidates for "the scientific method", i.e., the method for good reasoning for scientific purposes:

- Inductivism
- Falsificationism

Sample some important aspects of how science works:

- Scientific revolutions
- Scientific research programs
- Explanation and laws of nature
- The aims of science, good scientific practice



Scientific Method (1 serving)

1. Ask a question.
2. Formulate a hypothesis.
3. Perform experiment.
4. Collect data.
5. Draw conclusions.

Bake until thoroughly cooked.
Garnish with additional observations.

© http://undsci.berkeley.edu/article/howscienceworks_01

Lecture #2 (Oct. 26, 2015)

Text: Bacon, *New Organon*

Francis Bacon (1561-1626)

Life:

- Son of sir Nicholas Bacon, Lord Keeper of the Great Seal
- Student at Trinity College, Cambridge (contact with Scholasticism)
- Student at Gray's Inn
- Barrister, member of the House of Commons
- Solicitor General, Attorney General
- Lord Chancellor
- Baron Verulam, Viscount St. Albans

Bacon was a politician, statesman, and high government servant, not a philosopher or scientist

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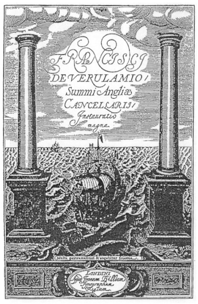
Francis Bacon, works



1597	*Essays* (1st edition)
1603-1605	*The Advancement of Learning*
1610	*New Atlantis* (publ. 1626)
1612	*Essays* (extended edition)
1620	*Novum Organum* (begun around 1608)
1623	*De Dignitate et Augmentis Scientiarum*
1625	*Essays* (final edition)

- Observation that science was in a bad condition – lack of progress
- Rejection of uncritical acceptance of myths, belief in miracles, testimony, authoritative texts

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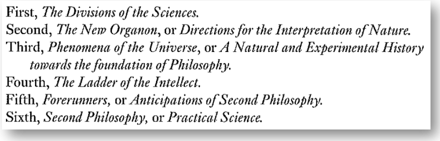
The *Novum Organum*

- Incomplete work: planned as part of the *Instauratio Magna*, the "Great Renewal" of learning
- Six parts:



First, *The Divisions of the Sciences.*
Second, *The New Organon*, or *Directions for the Interpretation of Nature.*
Third, *Phenomena of the Universe*, or *A Natural and Experimental History towards the foundation of Philosophy.*
Fourth, *The Ladder of the Intellect.*
Fifth, *Forerunners*, or *Anticipations of Second Philosophy.*
Sixth, *Second Philosophy*, or *Practical Science.*

Tradition	Bacon's program
- deductive method	- inductive method
- „gentlemen scholarschip"	- science as a cooperative enterprise
- uncritical acceptance of claims made by others	- open criticism

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Bacon's program (1)

Opposition against the old, established forms of obtaining knowledge (Scholasticism):

- Authority of the Church, Scripture, and the works of Aristotle
- Deduction of knowledge claims from the available texts
- Obtaining knowledge = recovering knowledge that has been lost (is buried in the authoritative texts)

Reflection on how science could be done better:

- What procedures can be followed that (1) lead us to knowledge claims & (2) justifies these claims? (Ladyman, p. 15)
- Development of new tools for producing knowledge
- Reflection on the nature of science – the aims of science determine how science should be done
- Science as not fundamentally distinct from engineering, building machines to improve the lives of the people

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Bacon's program (2)

Lack of progress as compared with more practical fields:

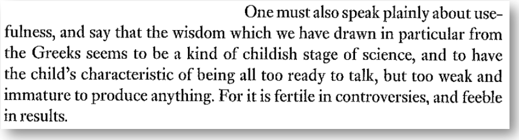
- "the sciences are almost stopped in their tracks, and show no developments worthy of the human race. […] In the mechanical arts we see the opposite situation. They grow and improve every day as if they breathed some vital breeze." (p. 7)
- The mechanical arts – machine building – often work in a crude way, from the bottom up, but gain elegance and knowledge as they go along
- Adverse effects of the popular views: "if profound thoughts have occasionally flared up, they have soon been blown on by the winds of common opinion and put out" (p. 8)
- Adverse effects of too great respect: "you can hardly admire an author and at the same time go beyond him" (p. 9)

Bacon's program (3)

Criticism of the state of affairs:

- "Men seem […] to have no good sense of either their resources or their power; but to exaggerate the former and underrate the latter." (p. 6)
- "they are like fatal pillars of Hercules to the sciences" (p. 6)
- Satisfaction with available knowledge – but there is much more to obtain if we would only dare to go further!

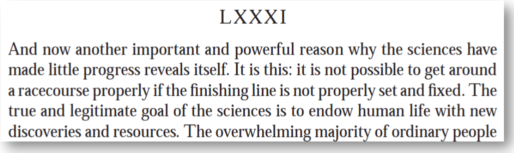
Emphasis on use:



One must also speak plainly about usefulness, and say that the wisdom which we have drawn in particular from the Greeks seems to be a kind of childish stage of science, and to have the child's characteristic of being all too ready to talk, but too weak and immature to produce anything. For it is fertile in controversies, and feeble in results.

Bacon's program (4)

Emphasis on use (continued):



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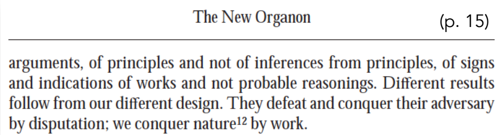
And now another important and powerful reason why the sciences have made little progress reveals itself. It is this: it is not possible to get around a racecourse properly if the finishing line is not properly set and fixed. The true and legitimate goal of the sciences is to endow human life with new discoveries and resources. The overwhelming majority of ordinary people

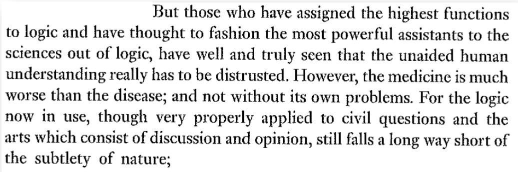


The New Organon (p. 15)

arguments, of principles and not of inferences from principles, of signs and indications of works and not probable reasonings. Different results follow from our different design. They defeat and conquer their adversary by disputation; we conquer nature[12] by work.

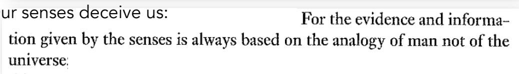
Bacon's program (5)

The available reasoning tool is flawed:



But those who have assigned the highest functions to logic and have thought to fashion the most powerful assistants to the sciences out of logic, have well and truly seen that the unaided human understanding really has to be distrusted. However, the medicine is much worse than the disease; and not without its own problems. For the logic now in use, though very properly applied to civil questions and the arts which consist of discussion and opinion, still falls a long way short of the subtlety of nature;

Our senses deceive us:

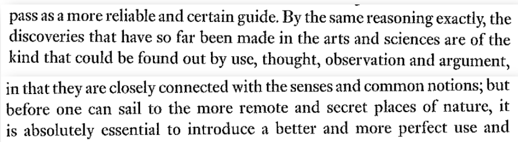


For the evidence and information given by the senses is always based on the analogy of man not of the universe;

Bacon searches for a "sure method" (p. 10)

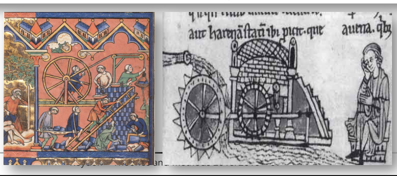
Bacon's program (6)

We have gotten as far as we can get by the available means:



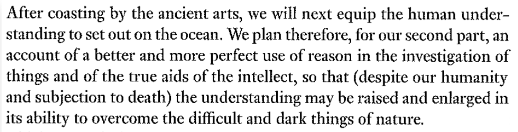
pass as a more reliable and certain guide. By the same reasoning exactly, the discoveries that have so far been made in the arts and sciences are of the kind that could be found out by use, thought, observation and argument,

in that they are closely connected with the senses and common notions; but before one can sail to the more remote and secret places of nature, it is absolutely essential to introduce a better and more perfect use and application of the mind and understanding.



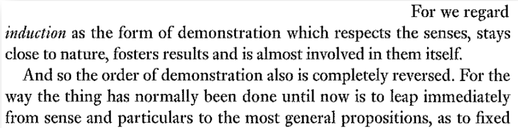
Bacon's program (7)

A new scientific method (p. 15):



After coasting by the ancient arts, we will next equip the human understanding to set out on the ocean. We plan therefore, for our second part, an account of a better and more perfect use of reason in the investigation of things and of the true aids of the intellect, so that (despite our humanity and subjection to death) the understanding may be raised and enlarged in its ability to overcome the difficult and dark things of nature.

"The logicians seem scarcely to have thought about induction":



For we regard *induction* as the form of demonstration which respects the senses, stays close to nature, fosters results and is almost involved in them itself.

And so the order of demonstration also is completely reversed. For the way the thing has normally been done until now is to leap immediately from sense and particulars to the most general propositions, as to fixed

The idols (1)

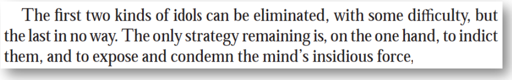
Proposition of a method to avoid flaws in human reasoning:

- Scientific method to offset "idols of the mind" (Ladyman, pp. 22-23)
- "The *Idols* by which the mind is occupied are either artificial or innate" (p. 18)
- See aphorisms XXXVIII – XLIV ("illusions and false notions which block men's minds")
- Idols of the tribe: innate tendency to see order and regularity everywhere (even where nature might not be well-ordered)
- Idols of the tribe are common to all human beings (part of "human nature")
- Idols of the cave: personal preferences and inclinations that determine one's interpretation of observations & acceptance of claims and theories
- Idols of the cave are personal (everyone sits in his/her own cave)

The idols (2)

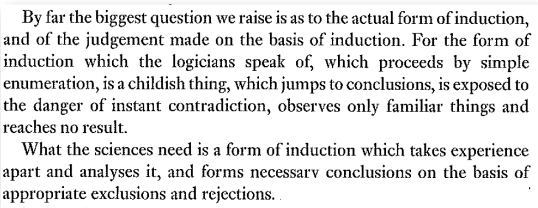
Proposition of a method to avoid flaws in human reasoning:

- Idols of the marketplace: aspects of language that affect our thinking (we trade our claims with others in the "marketplace of claims" using language)
- Idols of the marketplace are specific to a language community
- Idols of the theatre: accepted systems of thought that confine us
- Idols of the theatre are specific for a society
- The artificial idols can be removed, the innate idols cannot – but they can be exposed (p. 19, p. 41)


The first two kinds of idols can be eliminated, with some difficulty, but the last in no way. The only strategy remaining is, on the one hand, to indict them, and to expose and condemn the mind's insidious force,

Bacon's method of induction (1)

Not simple enumerative induction (see next week),
but a more complicated method:

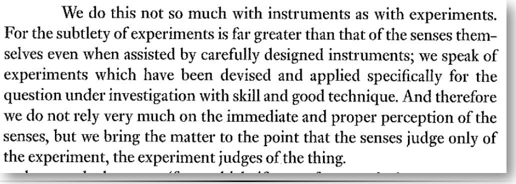

By far the biggest question we raise is as to the actual form of induction, and of the judgement made on the basis of induction. For the form of induction which the logicians speak of, which proceeds by simple enumeration, is a childish thing, which jumps to conclusions, is exposed to the danger of instant contradiction, observes only familiar things and reaches no result.

What the sciences need is a form of induction which takes experience apart and analyses it, and forms necessary conclusions on the basis of appropriate exclusions and rejections.

(p. 17)

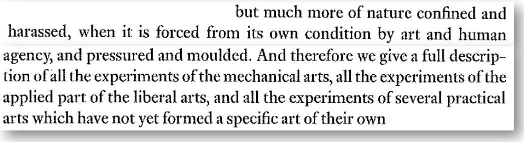
Bacon's method of induction (2)

- Start by making unprejudiced observations
- Use instruments to correct our natural senses
- Do experiments: rather than simply observing nature, try to control the environment to systematically make observations under all possible sets of conditions (p. 18)
(That is: try to make observations for all possible sets of all possible values of the variables that describe your system)


We do this not so much with instruments as with experiments. For the subtlety of experiments is far greater than that of the senses themselves even when assisted by carefully designed instruments; we speak of experiments which have been devised and applied specifically for the question under investigation with skill and good technique. And therefore we do not rely very much on the immediate and proper perception of the senses, but we bring the matter to the point that the senses judge only of the experiment, the experiment judges of the thing.

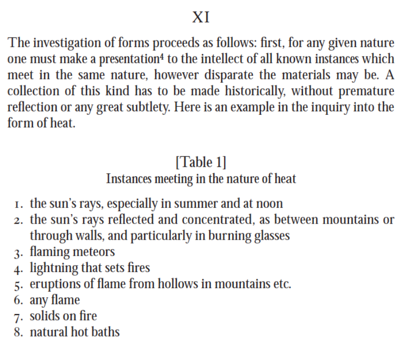
Bacon's method of induction (3)

- Natural history (Part 3) is experiment-based (p. 20):


but much more of nature confined and harassed, when it is forced from its own condition by art and human agency, and pressured and moulded. And therefore we give a full description of all the experiments of the mechanical arts, all the experiments of the applied part of the liberal arts, and all the experiments of several practical arts which have not yet formed a specific art of their own

- Amass observations: good inductions are based on as much data as you can gather
- Carefully build on your data, ascend the ladder of induction step by step
(Objection to the old science: they jumped to conclusions)
- Use tables to systematically determine commonalities, differences, absences, etc.

Bacon's method of induction (4)


XI

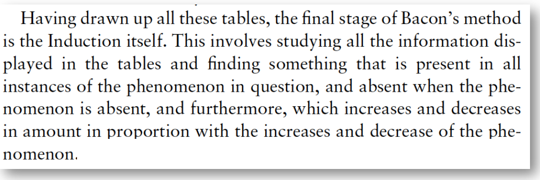
The investigation of forms proceeds as follows: first, for any given nature one must make a presentation[4] to the intellect of all known instances which meet in the same nature, however disparate the materials may be. A collection of this kind has to be made historically, without premature reflection or any great subtlety. Here is an example in the inquiry into the form of heat.

[Table 1]
Instances meeting in the nature of heat

1. the sun's rays, especially in summer and at noon
2. the sun's rays reflected and concentrated, as between mountains or through walls, and particularly in burning glasses
3. flaming meteors
4. lightning that sets fires
5. eruptions of flame from hollows in mountains etc.
6. any flame
7. solids on fire
8. natural hot baths

Bacon's method of induction (4)

Induction as the scientific method:


Having drawn up all these tables, the final stage of Bacon's method is the Induction itself. This involves studying all the information displayed in the tables and finding something that is present in all instances of the phenomenon in question, and absent when the phenomenon is absent, and furthermore, which increases and decreases in amount in proportion with the increases and decrease of the phenomenon.

- Method of elimination: systematically exclude factors
- End: knowledge of the true forms of things
(i.e., the true causes of a phenomenon)
- Cause: that factor which is found to always go together with the phenomenon in question, and to never be present when the phenomenon is not present (!!!)

"Knowledge is power" (1)

- "so that the mind may exercise its right over nature" (p. 6)
- "we conquer nature by work" (p. 16)
- The aim of science (p. 13):

> we want all and everyone to be advised to reflect on the true ends of knowledge:[10] not to seek it for amusement or for dispute, or to look down on others, or for profit or for fame or for power or any such inferior ends, but for the uses and benefits of life, and to improve and conduct it in charity.

- General knowledge makes specific works possible (p. 20):

> For although our ultimate aim is works and the active part of science, still we wait for harvest time and do not try to reap moss and the crop while it is still green. We know very well that axioms properly discovered bring whole companies of works with them, revealing them not singly but in quantity.

"Knowledge is power" (2)

- Science is aimed at knowledge of causes (p. 24):

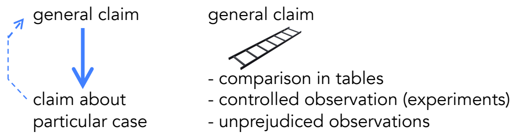
> No strength exists that can interrupt or break the chain of causes; and nature is conquered only by obedience. Therefore those two goals of man, *knowledge* and *power*, a pair of twins, are really come to the same thing, and works are chiefly frustrated by ignorance of causes.

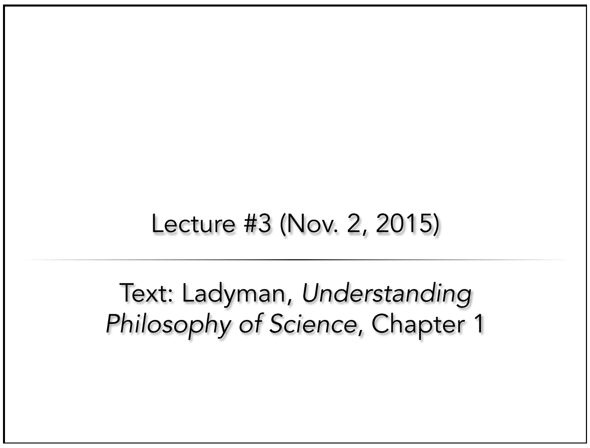
> But any man whose care and concern is not merely to be content with what has been discovered and make use of it, but to penetrate further; and not to defeat an opponent in argument but to conquer nature by action; and not to have nice, plausible opinions about things but sure, demonstrable knowledge; let such men (if they please), as true sons of the sciences, join with me, so that we may pass the antechambers of nature which innumerable others have trod, and eventually open up access to the inner rooms.

(p. 30)

Understanding Bacon

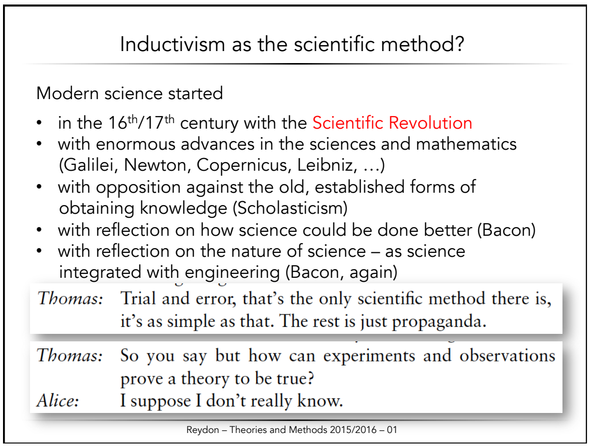
- Writing style in the late 16th / early 17th century was very different from what it is nowadays
- Bacon was not a systematically arguing philosopher
- The *Novum Organum* is more a (very lengthy) manifesto than a philosophical treatise
- Aim: to explain the new method & to convince people of the new method – not to provide systematic foundations for that method
- Method:





Lecture #3 (Nov. 2, 2015)

Text: Ladyman, *Understanding Philosophy of Science*, Chapter 1



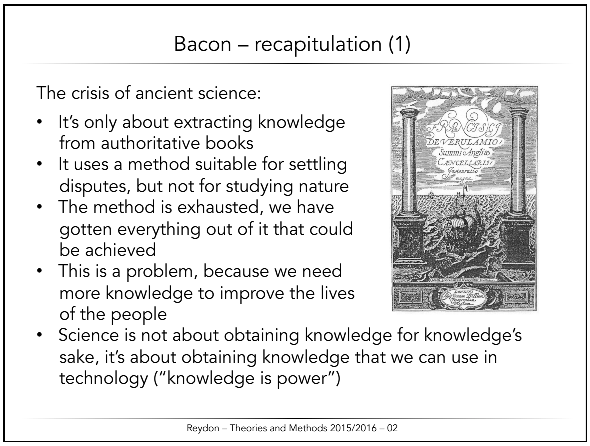
Inductivism as the scientific method?

Modern science started

- in the 16th/17th century with the Scientific Revolution
- with enormous advances in the sciences and mathematics (Galilei, Newton, Copernicus, Leibniz, …)
- with opposition against the old, established forms of obtaining knowledge (Scholasticism)
- with reflection on how science could be done better (Bacon)
- with reflection on the nature of science – as science integrated with engineering (Bacon, again)

Thomas: Trial and error, that's the only scientific method there is, it's as simple as that. The rest is just propaganda.

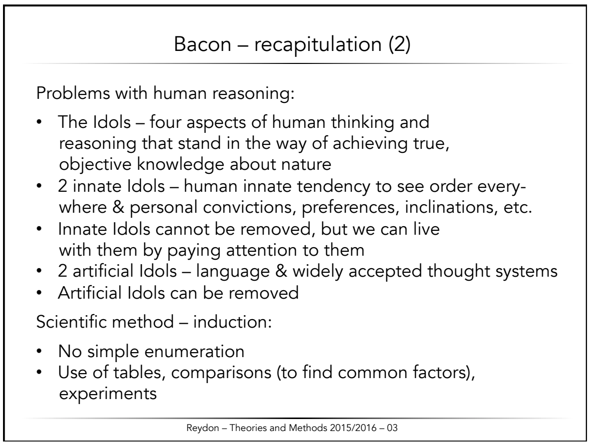
Thomas: So you say but how can experiments and observations prove a theory to be true?
Alice: I suppose I don't really know.



Bacon – recapitulation (1)

The crisis of ancient science:

- It's only about extracting knowledge from authoritative books
- It uses a method suitable for settling disputes, but not for studying nature
- The method is exhausted, we have gotten everything out of it that could be achieved
- This is a problem, because we need more knowledge to improve the lives of the people
- Science is not about obtaining knowledge for knowledge's sake, it's about obtaining knowledge that we can use in technology ("knowledge is power")



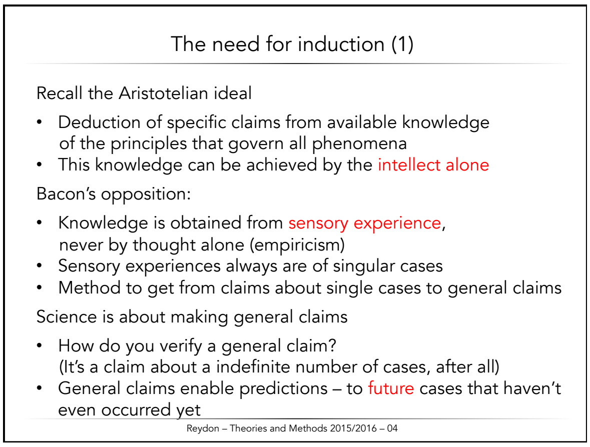
Bacon – recapitulation (2)

Problems with human reasoning:

- The Idols – four aspects of human thinking and reasoning that stand in the way of achieving true, objective knowledge about nature
- 2 innate Idols – human innate tendency to see order everywhere & personal convictions, preferences, inclinations, etc.
- Innate Idols cannot be removed, but we can live with them by paying attention to them
- 2 artificial Idols – language & widely accepted thought systems
- Artificial Idols can be removed

Scientific method – induction:

- No simple enumeration
- Use of tables, comparisons (to find common factors), experiments



The need for induction (1)

Recall the Aristotelian ideal

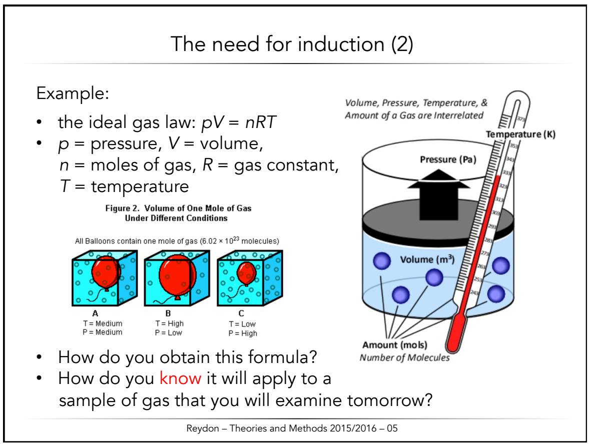
- Deduction of specific claims from available knowledge of the principles that govern all phenomena
- This knowledge can be achieved by the intellect alone

Bacon's opposition:

- Knowledge is obtained from sensory experience, never by thought alone (empiricism)
- Sensory experiences always are of singular cases
- Method to get from claims about single cases to general claims

Science is about making general claims

- How do you verify a general claim?
  (It's a claim about a indefinite number of cases, after all)
- General claims enable predictions – to future cases that haven't even occurred yet



The need for induction (2)

Example:

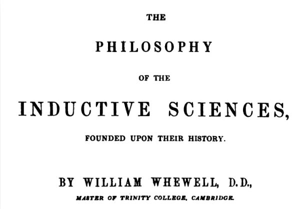
- the ideal gas law: $pV = nRT$
- p = pressure, V = volume,
  n = moles of gas, R = gas constant,
  T = temperature

Figure 2. Volume of One Mole of Gas Under Different Conditions

- How do you obtain this formula?
- How do you know it will apply to a sample of gas that you will examine tomorrow?

Induction as the scientific method

Up to the late 19th century the natural sciences were called the inductive sciences


THE

PHILOSOPHY

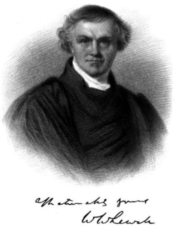
OF THE

INDUCTIVE SCIENCES,

FOUNDED UPON THEIR HISTORY.

BY WILLIAM WHEWELL, D.D.,

MASTER OF TRINITY COLLEGE, CAMBRIDGE.



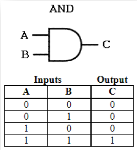
(Whewell, 1847)

Whewell stood in Bacon's line ("*Novum Organum Renovatum*")

Some basic logic: deduction & induction (1)

Logic is the study of reasoning (Ladyman, p. 19):

- When I know that claim *p* is true & I know that claim *q* is true, how do I get from there to knowledge that *r* is true, if I don't already know this to be the case?
- We reason from what we know to new claims that we don't yet know
- If we have good tools to do this, we can produce new knowledge on the basis of what we already have
- Are there any such tools?



Inputs		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Note:

- Logic is about the form of arguments, not their content ("*If* p and q are true, *then* it follows that …")
- The issue is validity of argumentative structures

Some basic logic: deduction & induction (2)

Deduction

All Fs are Gs
(e.g.: All swans are white)

Object o_1 is an F
(o_1 is a swan)

So o_1 is a G
(o_1 is white)

General claim
Particular case

Induction

o_1 is an F that is also a G
o_2 is an F that is also a G
o_3 is an F that is also a G
…
(So far all observed swans were white)

So all Fs are Gs
(All swans are white)

Particular cases
General claim

The problem of induction (next lecture)

The problem of induction (next lecture)

Either
"All swans are white" is not true
or
this particular case does not involve a swan

Some basic logic: deduction & induction (3)

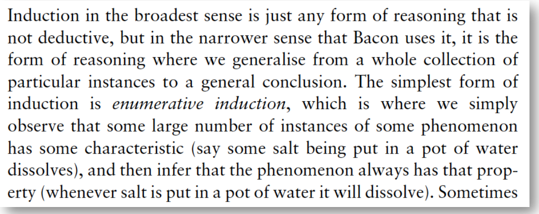
Deductive arguments:

- Preserve truth: if all premises are true & the argument (structure) is valid, the conclusion is necessarily true
- What's in the conclusion is already included in the premises
- You don't get new knowledge, you only make explicit what you already knew

Inductive arguments:

- Do not preserve truth
- Are risky: they involve jumping to the conclusion (cf. Bacon's criticism of the Scholastics)
- The conclusion contains more knowledge than all the premises taken together (except for fully known finite sets)
- Some are better (more convincing, more acceptable, etc.) than others

Some basic logic: deduction & induction (4)



Induction in the broadest sense is just any form of reasoning that is not deductive, but in the narrower sense that Bacon uses it, it is the form of reasoning where we generalise from a whole collection of particular instances to a general conclusion. The simplest form of induction is *enumerative induction*, which is where we simply observe that some large number of instances of some phenomenon has some characteristic (say some salt being put in a pot of water dissolves), and then infer that the phenomenon always has that property (whenever salt is put in a pot of water it will dissolve). Sometimes

(Ladyman, p. 28)

- Does it matter how many individual instances you have observed? (2 or 3 cannot be sufficient, but if you have 10.000 of the same observations…)
- How do we know that we're observing the same phenomenon in all these cases?

Some basic logic: deduction & induction (5)

Some issues:

- Inductive arguments are logically invalid
- Baconian induction might not lead to a unique cause – there may be multiple factors that go together with the phenomenon under consideration
- Table shows multiple coinciding factors
- In such cases Bacon's method cannot break the deadlock

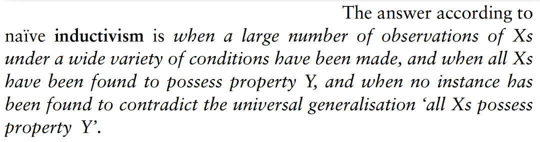
Crucial experiments (again: Bacon):

- Experiments that can decide between two possible causes
- No unprejudiced observation, but guided by theory (designed to test theories against one another, not to make observations under different sets of conditions)
- Two outcomes, one for each candidate theory
- (Discussion on whether such experiments are possible at all?)

Inductivism

When is it legitimate to infer a universal generalisation from a collection of observation statements? (Ladyman, p. 28)

Naïve inductivism:

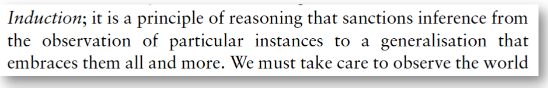


The answer according to naïve **inductivism** is *when a large number of observations of Xs under a wide variety of conditions have been made, and when all Xs have been found to possess property Y, and when no instance has been found to contradict the universal generalisation 'all Xs possess property Y'.*

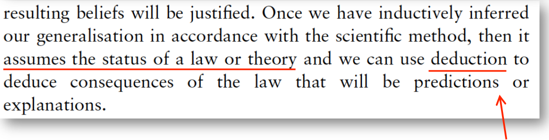
→ The question for you: is this at all plausible? (Next week: problems of induction)

The scientific method? (1)

The naïve inductivist's principle of induction as the scientific method (Ladyman, p. 29):



Induction; it is a principle of reasoning that sanctions inference from the observation of particular instances to a generalisation that embraces them all and more. We must take care to observe the world



resulting beliefs will be justified. Once we have inductively inferred our generalisation in accordance with the scientific method, then it assumes the status of a law or theory and we can use deduction to deduce consequences of the law that will be predictions or explanations.

→ Another question for you: is this at all plausible? (Hint: what does the status jump consist in?)

$pV = nRT$

The scientific method? (2)

Some problems:

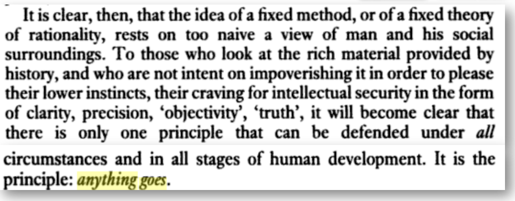
- How do you know the principle of induction is true, or valid, or acceptable as a basis for reasoning?
- How do you know which observations count for the case you are considering without having a concept first? (How do you know the bird you are looking at is a swan? You recognize swans by their traits – but you're trying to infer what their traits are in the first place)
- Observations are supposed to be free from any preconceptions – you are supposed to observe the world as it really is
- Unbiased observation is impossible

→ Problems with induction: next session

The scientific method? (4)

Why think there is one scientific method in the first place?

- "I am inclined to believe that "science" in the abstract is a phantom" (T.S. Eliot, 1927)
- Paul Feyerabend, *Against Method* (1993: 18-19):



It is clear, then, that the idea of a fixed method, or of a fixed theory of rationality, rests on too naive a view of man and his social surroundings. To those who look at the rich material provided by history, and who are not intent on impoverishing it in order to please their lower instincts, their craving for intellectual security in the form of clarity, precision, 'objectivity', 'truth', it will become clear that there is only one principle that can be defended under *all* circumstances and in all stages of human development. It is the principle: *anything goes*.

Lecture #4 (Nov. 9, 2015)

Text: Ladyman, *Understanding Philosophy of Science*, Chapter 2

Logic recap

Preserves truth **Deduction**	Does not preserve truth **Induction**
If	If
All Fs are Gs is true	o_1 is an F that is also a G
(e.g.: All swans are white)	o_2 is an F that is also a G
and	o_3 is an F that is also a G
Object o_1 is an F is true	… all are true
(o_1 is a swan)	(So far all observed swans were white)
then it follows that	then it still doesn't follow that
o_1 is a G	All Fs are Gs
(o_1 is white)	(All swans are white)
General claim Particular case	Particular cases General claim

Two questions: Do you find this plausible?

When is an inference to a universal generalization legitimate?

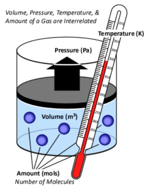
> The answer according to naïve **inductivism** is *when a large number of observations of Xs under a wide variety of conditions have been made, and when all Xs have been found to possess property Y, and when no instance has been found to contradict the universal generalisation 'all Xs possess property Y'.*

What does induction do for us?

> Once we have inductively inferred our generalisation in accordance with the scientific method, then it assumes the status of a law or theory and we can use deduction to deduce consequences of the law that will be predictions or explanations.

Recap (1)

Example, the ideal gas law ($pV = nRT$):



- How do you obtain this formula?
  - Wild guess
  - Extrapolation from empirical observations (induction?)
- How do you know it will apply to a sample of gas that you will examine tomorrow?
  - If it's true, it will apply tomorrow
  - How do you know it's true? – back at square one
- Who cares about truth anyway?
  - If it's confirmed, validated, empirically supported, … then it will apply tomorrow
  - How do you know whether it's confirmed, …?
  - You need a method/theory of confirmation – and induction is a candidate

---

Recap (2)

Some problems regarding induction as a method of reasoning:

- Principle: How do you know the principle of induction is true, or valid, or acceptable as a basis for reasoning?
- Basis of induction: How do you know which observations count for the case you are considering? (If you find that an observation conflicts with "All swans are white", then either not all swans are white or the bird you saw wasn't a swan)
- Basis of induction: Observations are supposed to be free from any preconceptions – you are supposed to observe the world as it really is (which is impossible)
- Induction is not a logically valid argumentative structure in the first place

---

The problem of induction

David Hume, *A Treatise of Human Nature* (1739-1740):

- There are no arguments that could show „that instances of which we have had no experience, must resemble those of which we have had experience, and that the course of nature continues always uniformly the same" (*Treatise*. I.III.VI, p. 89)
- The issue is whether induction understood as prediction is warranted (I've seen the sun come up many times, so I predict that it will rise tomorrow)
- Inductions are based on habits:
  - There is no logical principle that supports induction
  - There is no empirical principle that supports induction

Hume's argument (1)

Two types of proposition, types of objects of thought & inquiry:

- Relations of ideas – statements about relations between concepts, can be known a priori
- Matters of fact – statements about the world "out there", can only be known empirically, a posteriori
- "Hume's fork": any proposition that is acceptable as knowledge should be either a relation of ideas or a matter of fact

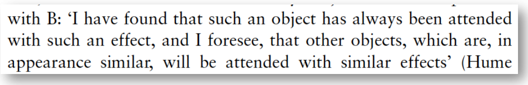
Experiential knowledge:

- All reasoning that goes beyond direct experience must be based on causes (Ladyman, p. 34)
- Predictions (inductions) must rest on knowledge about causes
- Causes cannot be known as relations of ideas
- So, if they can be known they must be known as matters of fact
- How can causes be known empirically?

Hume's argument (2)

Causation:

- Causes are known as constant conjunctions (Ladyman, p. 36)

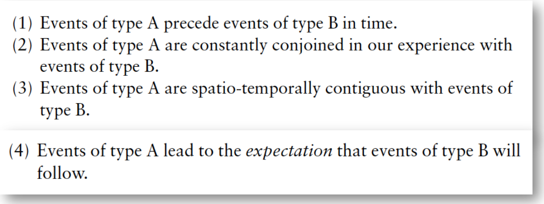


with B: 'I have found that such an object has always been attended with such an effect, and I foresee, that other objects, which are, in appearance similar, will be attended with similar effects' (Hume

- Reasoning from a recurring conjunction between two occurrences (b happens after a) to a causal connection (a causes b)
- Reasoning from this causal connection (a causes b) to future instances (the next time b will again happen after a)
- But to be able to do this, we need to believe that the future will resemble the past

Hume's argument (3)

Hume's analysis of causation:



(1) Events of type A precede events of type B in time.
(2) Events of type A are constantly conjoined in our experience with events of type B.
(3) Events of type A are spatio-temporally contiguous with events of type B.

(4) Events of type A lead to the *expectation* that events of type B will follow.

(Ladyman, pp. 36-37)

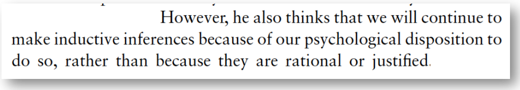
- Causal reasoning is a matter of habit – we never see causes, we only see one thing happening after the other
- Induction is based on causal reasoning, so is a matter of habit

---

Induction as a matter of habit (1)

Even though inductions are not supported:

- We're used to regularities in nature
- This leads us to count on such regularities in the future (tacit commitment to the uniformity of nature in space and time; Ladyman, p. 38)
- Induction isn't a form of argumentation, but a habit rooted in human nature

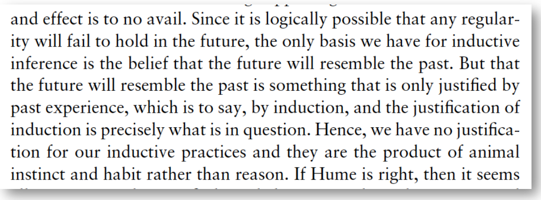


However, he also thinks that we will continue to make inductive inferences because of our psychological disposition to do so, rather than because they are rational or justified.

- Because it's not a form of argumentation, the lack of logical validity or of a supporting principle isn't a problem
- The other problems (lack of a good basis for induction) remain
- Has this replaced one problem by another?

Induction as a matter of habit (2)

The verdict:



and effect is to no avail. Since it is logically possible that any regularity will fail to hold in the future, the only basis we have for inductive inference is the belief that the future will resemble the past. But that the future will resemble the past is something that is only justified by past experience, which is to say, by induction, and the justification of induction is precisely what is in question. Hence, we have no justification for our inductive practices and they are the product of animal instinct and habit rather than reason. If Hume is right, then it seems

(Ladyman, p. 40)

Sceptical conclusion:

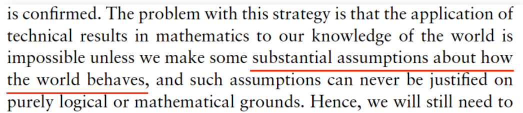
- No knowledge about causes in nature, we only see correlations
- No support for predictions, we just see individual cases
- No support for empirical generalizations

Rescuing induction? (1)

Believing in induction is rational by definition – most people find it rational:

- Trust in induction is deep-seated
- We could not live our lives without induction
- Therefore Hume's argument must be problematic
- Hume's argument shows problems when trying to justify induction
- But it does not show that induction is generally unjustifiable
- So we have to search for other ways to justify induction

Justification by the theory of probability? (Ladyman, p. 43)



is confirmed. The problem with this strategy is that the application of technical results in mathematics to our knowledge of the world is impossible unless we make some substantial assumptions about how the world behaves, and such assumptions can never be justified on purely logical or mathematical grounds. Hence, we will still need to

Intermezzo: Why doesn't probability help?

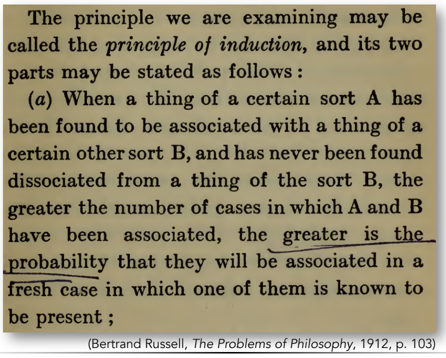
Degrees of belief (Ladyman, p. 50-51):

- The idea: jump from knowing nothing about "All As are Bs" to absolute certainty *that* "All As are Bs" is true
- Alternative: believing a claim comes in degrees
- More supporting observations ⇒ higher degree of belief (It's about your acceptance of a claim)
- This is based on observed frequencies, but
  - What if the number of possible cases is 100?
  - What if the number of possible cases is infinite?
  - What if you don't know the number of possible cases?

For Hume it was a matter about the world:

- Inductions only work if tomorrow is the same as today
- E.g.: the frequency of white/black swans must remain the same
- There is no reason to believe in the uniformity of nature

Rescuing induction? (2)

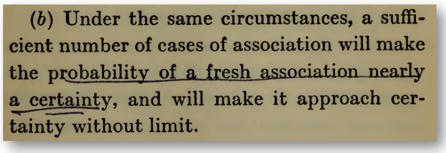


The principle we are examining may be called the *principle of induction*, and its two parts may be stated as follows:

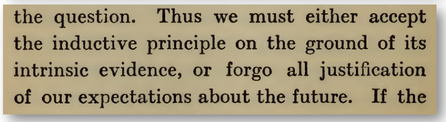
(*a*) When a thing of a certain sort A has been found to be associated with a thing of a certain other sort B, and has never been found dissociated from a thing of the sort B, the greater the number of cases in which A and B have been associated, the greater is the probability that they will be associated in a fresh case in which one of them is known to be present;

(Bertrand Russell, *The Problems of Philosophy*, 1912, p. 103)

Rescuing induction? (3)



(*b*) Under the same circumstances, a sufficient number of cases of association will make the probability of a fresh association nearly a certainty, and will make it approach certainty without limit.



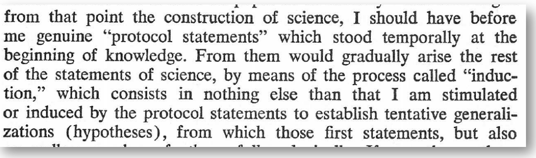
the question. Thus we must either accept the inductive principle on the ground of its intrinsic evidence, or forgo all justification of our expectations about the future. If the

(Bertrand Russell, *The Problems of Philosophy*, 1912, p. 103-106)

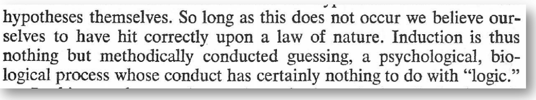
- Pragmatic justification of the principle as self-evident
- But is this a justification at all?

Rescuing induction? (4)

Moritz Schlick, "On the foundation of knowledge" (1934):



from that point the construction of science, I should have before me genuine "protocol statements" which stood temporally at the beginning of knowledge. From them would gradually arise the rest of the statements of science, by means of the process called "induction," which consists in nothing else than that I am stimulated or induced by the protocol statements to establish tentative generalizations (hypotheses), from which those first statements, but also

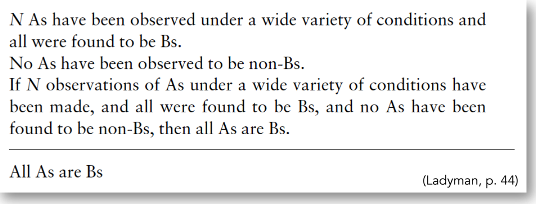


hypotheses themselves. So long as this does not occur we believe ourselves to have hit correctly upon a law of nature. Induction is thus nothing but methodically conducted guessing, a psychological, biological process whose conduct has certainly nothing to do with "logic."

- Induction as legitimate guessing

Rescuing induction? (5)

Justification by adding a principle of the uniformity of nature:



N As have been observed under a wide variety of conditions and all were found to be Bs.
No As have been observed to be non-Bs.
If *N* observations of As under a wide variety of conditions have been made, and all were found to be Bs, and no As have been found to be non-Bs, then all As are Bs.

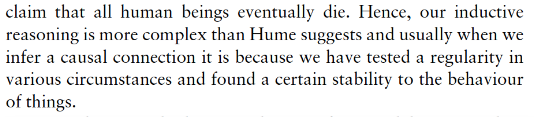
All As are Bs

(Ladyman, p. 44)

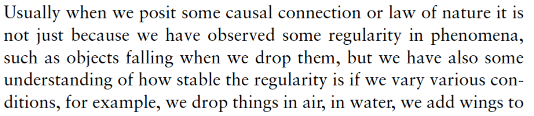
- How large does N need to be?
- Discrete transition from no reason to believe the conclusion (# obs. < N) to knowing it with certainty (# obs. ≧ N)
- It doesn't get any better with # obs. = N + 1

Rescuing induction? (6)

No justification of induction itself, but providing external support for particular inductive inferences (with experiments):

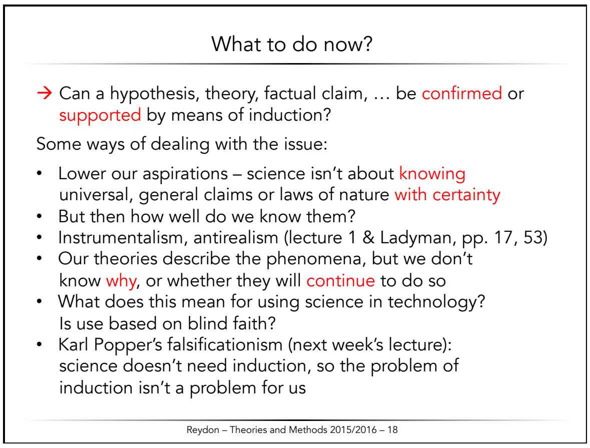


claim that all human beings eventually die. Hence, our inductive reasoning is more complex than Hume suggests and usually when we infer a causal connection it is because we have tested a regularity in various circumstances and found a certain stability to the behaviour of things.



Usually when we posit some causal connection or law of nature it is not just because we have observed some regularity in phenomena, such as objects falling when we drop them, but we have also some understanding of how stable the regularity is if we vary various conditions, for example, we drop things in air, in water, we add wings to

(Ladyman, p. 46-48)



What to do now?

→ Can a hypothesis, theory, factual claim, … be confirmed or supported by means of induction?

Some ways of dealing with the issue:

- Lower our aspirations – science isn't about knowing universal, general claims or laws of nature with certainty
- But then how well do we know them?
- Instrumentalism, antirealism (lecture 1 & Ladyman, pp. 17, 53)
- Our theories describe the phenomena, but we don't know why, or whether they will continue to do so
- What does this mean for using science in technology? Is use based on blind faith?
- Karl Popper's falsificationism (next week's lecture): science doesn't need induction, so the problem of induction isn't a problem for us

Lecture #5 (Nov. 16, 2015)

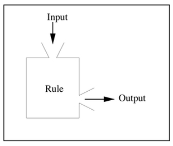
Texte: Popper, *Logic of Scientific Discovery* & Ladyman, *Understanding Philosophy of Science*, Chapter 3

Recap: logic

Two reasoning methods:

- Deduction is logically valid but doesn't provide new knowledge
- Induction is not logically valid but would provide new knowledge

Logic:



- "Machine" that gets you from input to output
- Valid rules tell you how to get from input to output
- What you get out of the machine is what you've put into it in the first place
- Truth conserving: it the premises are true, the conclusion must be true also
- Deduction: if "All Xs are Ys" is true and if "O is an X" is true, then "O is a Y" must be true – but this is not new knowledge

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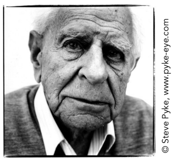
Karl Popper



The author:

- Born 1902 in Vienna, died 1994 in London
- Contacts with the intellectual elite of his time – Vienna Circle, Russell, Schrödinger, Gombrich, Hayek, …
- Professor of Logic and Scientific Method, Dept. of Philosophy, Logic and Scientific Method, LSE
- One of the best known philosophers of science
- Founder of critical rationalism, falsificationism
- Worked among other things on evolutionary epistemology ("All life is problem solving")
- Knowledge as problem-solving tool, not as objective representation of what the world is like

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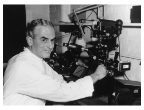
Popper's influence

„There is no more to science than its method, and there is no more to its method than Popper has said."

(Hermann Bondi, in Magee, 1973, p. 9)

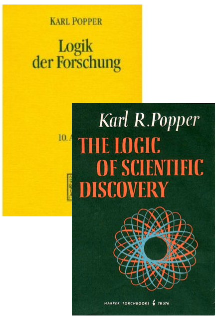
„I think Popper is incomparably the greatest philosopher of science that has ever been."

(Peter Medawar, 1972; in Magee, 1973, p. 9)



Otto Neurath described Popper as the "official opposition" of the Vienna Circle (Note that induction was an important theme for the Vienna Circle and related philosophers)

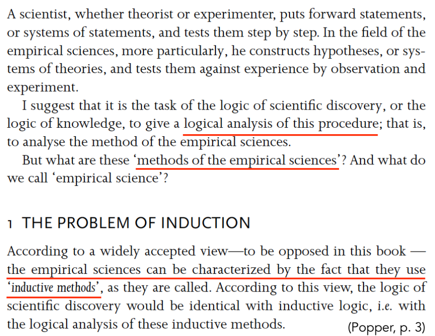
Karl Popper's *LSD*



The book:

- German version 1934
  English version 1959
- Tries to solve the two main problems of the theory of knowledge (p. 11):
  - The problem of induction
  - The demarcation problem
- Science is not fundamentally different from everyday practices of knowledge production
- Still, there is a demarcation line
- Note: Logic of scientific discovery
- Popular with practicing scientists, recognizable method

Intro to *LSD* (1)



A scientist, whether theorist or experimenter, puts forward statements, or systems of statements, and tests them step by step. In the field of the empirical sciences, more particularly, he constructs hypotheses, or systems of theories, and tests them against experience by observation and experiment.

I suggest that it is the task of the logic of scientific discovery, or the logic of knowledge, to give a logical analysis of this procedure; that is, to analyse the method of the empirical sciences.

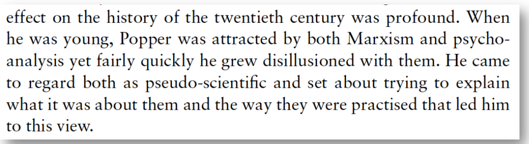
But what are these 'methods of the empirical sciences'? And what do we call 'empirical science'?

1 THE PROBLEM OF INDUCTION

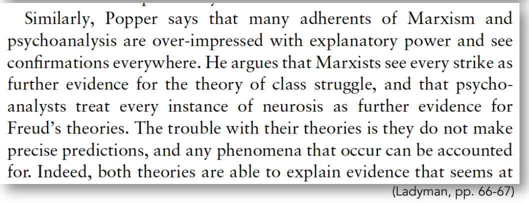
According to a widely accepted view—to be opposed in this book — the empirical sciences can be characterized by the fact that they use 'inductive methods', as they are called. According to this view, the logic of scientific discovery would be identical with inductive logic, *i.e.* with the logical analysis of these inductive methods.

(Popper, p. 3)

Intro to *LSD* (2)



effect on the history of the twentieth century was profound. When he was young, Popper was attracted by both Marxism and psychoanalysis yet fairly quickly he grew disillusioned with them. He came to regard both as pseudo-scientific and set about trying to explain what it was about them and the way they were practised that led him to this view.



Similarly, Popper says that many adherents of Marxism and psychoanalysis are over-impressed with explanatory power and see confirmations everywhere. He argues that Marxists see every strike as further evidence for the theory of class struggle, and that psychoanalysts treat every instance of neurosis as further evidence for Freud's theories. The trouble with their theories is they do not make precise predictions, and any phenomena that occur can be accounted for. Indeed, both theories are able to explain evidence that seems at

(Ladyman, pp. 66-67)

Karl Popper's *LSD*

The opposing view: induction as the scientific method
(for a good summary, incl. Hume's treatment: pp. 3-7)

The method (i.e., Popper's alternative):

- Start with a problem
- Formulate a hypothesis
- See if you can disprove the hypothesis
- If you can't you keep it as a possible solution to your problem

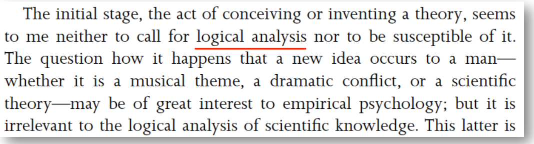
The formalism:

- Creative thinking: formulating a hypothesis is a creative process – scientists just come up with hypotheses
- Deduction: deduce empirically testable predictions from the hypothesis
- Falsification: if the predictions don't hold up, by logical consequence the hypothesis doesn't hold up (*modus tollens*)

Karl Popper's *LSD*

The formalism:

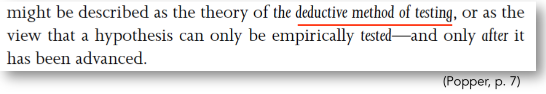
- Creative thinking:



The initial stage, the act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible of it. The question how it happens that a new idea occurs to a man—whether it is a musical theme, a dramatic conflict, or a scientific theory—may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. This latter is

(Popper, p. 7)

- Deduction: deduce empirically testable predictions

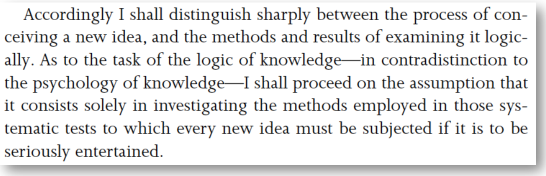


might be described as the theory of the *deductive method of testing*, or as the view that a hypothesis can only be empirically *tested*—and only *after* it has been advanced.

(Popper, p. 7)

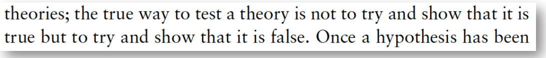
Karl Popper's *LSD*

The issue is "seriously entertaining" an idea – i.e., accepting, adopting, endorsing, not proving or knowing that it's true:



Accordingly I shall distinguish sharply between the process of conceiving a new idea, and the methods and results of examining it logically. As to the task of the logic of knowledge—in contradistinction to the psychology of knowledge—I shall proceed on the assumption that it consists solely in investigating the methods employed in those systematic tests to which every new idea must be subjected if it is to be seriously entertained.

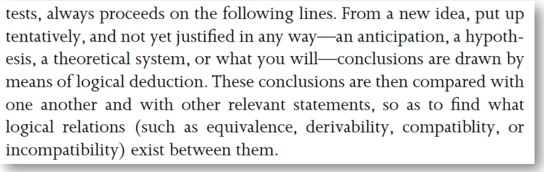
(Popper, p. 8)



theories; the true way to test a theory is not to try and show that it is true but to try and show that it is false. Once a hypothesis has been

(Ladyman, p. 70)

Method of testing



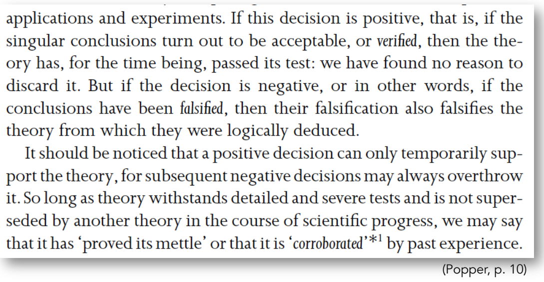
tests, always proceeds on the following lines. From a new idea, put up tentatively, and not yet justified in any way—an anticipation, a hypothesis, a theoretical system, or what you will—conclusions are drawn by means of logical deduction. These conclusions are then compared with one another and with other relevant statements, so as to find what logical relations (such as equivalence, derivability, compatiblity, or incompatibility) exist between them.

(Popper, p. 9)

Aspects of testing:

- Internal consistency
- Logical form (does it have empirical content)
- Comparison with rival theories
- Testing by means of empirical applications (deductive procedure)

Outcome of testing



applications and experiments. If this decision is positive, that is, if the singular conclusions turn out to be acceptable, or *verified*, then the theory has, for the time being, passed its test: we have found no reason to discard it. But if the decision is negative, or in other words, if the conclusions have been *falsified*, then their falsification also falsifies the theory from which they were logically deduced.

It should be noticed that a positive decision can only temporarily support the theory, for subsequent negative decisions may always overthrow it. So long as theory withstands detailed and severe tests and is not superseded by another theory in the course of scientific progress, we may say that it has 'proved its mettle' or that it is '*corroborated*'*[1] by past experience.

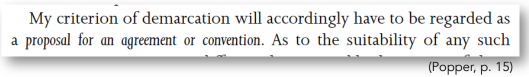
(Popper, p. 10)

Asymmetry between positive and negative outcomes:
verification is only provisional, falsification is final

Demarcation

The problem of demarcation:

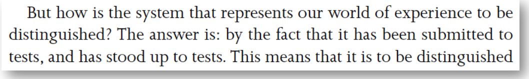
- What distinguishes science from metaphysics, non-science, pseudo-science, etc.?
- It's about the empirical sciences
- Traditional answer: the inductive method, which doesn't work
- Popper's alternative is a definition of the concept of science:



My criterion of demarcation will accordingly have to be regarded as a *proposal for an agreement or convention*. As to the suitability of any such

(Popper, p. 15)

- Experience is central as the basis of science:



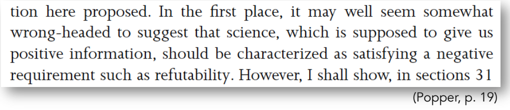
But how is the system that represents our world of experience to be distinguished? The answer is: by the fact that it has been submitted to tests, and has stood up to tests. This means that it is to be distinguished

(Popper, p. 17)

Falsification (1)

Decidability of statements (pp. 17-18):

- Logically any statement is either true or false
- Ideally decidability in a positive (prove their truth) and negative (prove their falsity) sense
- For general statements (laws of nature) the picture was:
  positive decisions follow from induction,
  negative decisions from finding a counterexample
- If induction doesn't work, we still have negative decidability



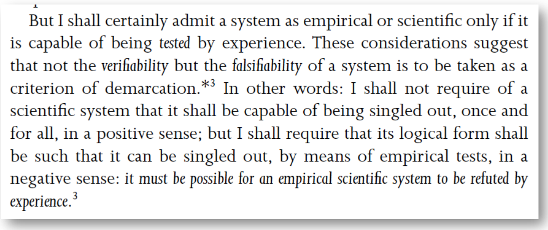
tion here proposed. In the first place, it may well seem somewhat wrong-headed to suggest that science, which is supposed to give us positive information, should be characterized as satisfying a negative requirement such as refutability. However, I shall show, in sections 31

(Popper, p. 19)

- Asymmetry between verification and falsification

Falsification (2)

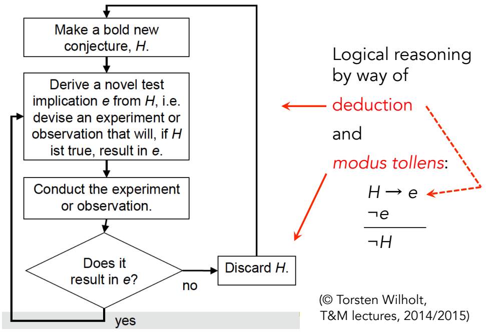
What makes science into science is the formulation of claims about nature that can fail on an empirical basis:



But I shall certainly admit a system as empirical or scientific only if it is capable of being *tested* by experience. These considerations suggest that not the *verifiability* but the *falsifiability* of a system is to be taken as a criterion of demarcation.*[3] In other words: I shall not require of a scientific system that it shall be capable of being singled out, once and for all, in a positive sense; but I shall require that its logical form shall be such that it can be singled out, by means of empirical tests, in a negative sense: *it must be possible for an empirical scientific system to be refuted by experience.*[3]

(Popper, p. 18)

The scientific method according to Popper



Logical reasoning by way of

deduction

and

modus tollens:

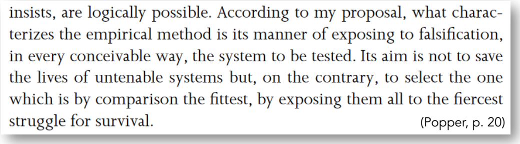
$$\frac{H \rightarrow e \quad \neg e}{\neg H}$$

(© Torsten Wilholt, T&M lectures, 2014/2015)

Falsification (cont.)

Remarks:

- The more information a statement contains the more it can fail to hold – the more counterexamples are possible
- The more tests are possible for a statement, the more information about the world it contains
- Evolutionary view:



insists, are logically possible. According to my proposal, what characterizes the empirical method is its manner of exposing to falsification, in every conceivable way, the system to be tested. Its aim is not to save the lives of untenable systems but, on the contrary, to select the one which is by comparison the fittest, by exposing them all to the fiercest struggle for survival.

(Popper, p. 20)

- Not: the more tests it has passed, the more true it is, the more reason we have for accepting it, etc.

Fallibilism

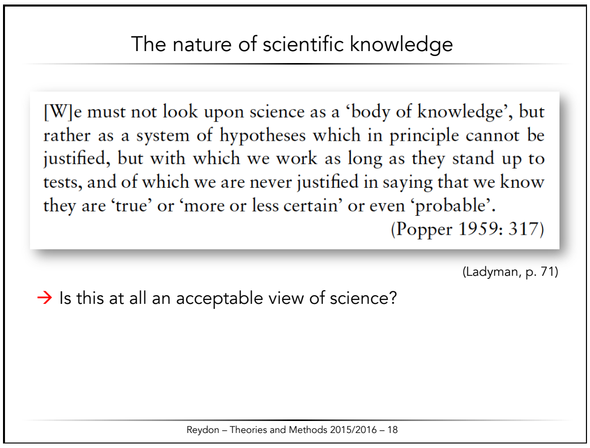
Science is fallible:

- Hypotheses, claims, etc. never become completely certain
- If many tests have been performed without falsifying the hypothesis, a new test may still falsify it tomorrow
- Therefore, all knowledge we have about the world is provisional

Positive methodology:

- Try to formulate hypotheses with as much empirical content as possible
- The empirical content of a hypothesis is the number of possible events that might disprove (falsify) it
- The larger the area of application, the larger the number of possible counterexamples
- E.g.: All metal objects conduct electricity
  All copper objects conduct electricity

non-conducting gold object?



The nature of scientific knowledge

> [W]e must not look upon science as a ‘body of knowledge’, but rather as a system of hypotheses which in principle cannot be justified, but with which we work as long as they stand up to tests, and of which we are never justified in saying that we know they are ‘true’ or ‘more or less certain’ or even ‘probable’.
> (Popper 1959: 317)

(Ladyman, p. 71)

→ Is this at all an acceptable view of science?

Lecture #6 (Nov. 23, 2015)

Text: Ladyman, *Understanding Philosophy of Science*, Chapter 3

Where to get theories & what to do with them?

Two contexts:

- Context of discovery:
  - Discovery of new knowledge claims, generating hypotheses, claims, etc.
  - Bacon: the production of theories and claims is a mechanical process (systematizing cases in tables, comparison, induction)
  - Any method is allowed: induction, dreaming up theories, speculation, personal preferences, …
- Context of justification:
  - Justifying, i.e., trying to support knowledge claims, hypotheses , theories, etc.
  - Testing: falsification, experimentation, …
  - Testing is susceptible to logical / methodological analysis

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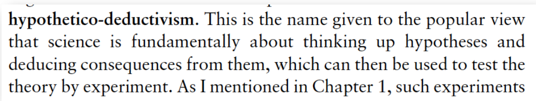
Testing

Separation of discovery & justification:

- Inductivism: induction is a method that both gives us new theories & hypotheses and supports them
- Hypothetico-deductivism:



hypothetico-deductivism. This is the name given to the popular view that science is fundamentally about thinking up hypotheses and deducing consequences from them, which can then be used to test the theory by experiment. As I mentioned in Chapter 1, such experiments

(Ladyman, p. 76)

- Popper's falsificationism is one version of hyp.-deductivism
- Distinctive of Popper's version: positive results do not count as gradually confirming the tested theory
- The evidence in favor of a hypothesis or theory is empirical & independent of how the hypothesis or theory originated

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Robert Merton's proposal (1)

Components of the professional ethos of science (1942):

- Universalism: truth-claims are to be evaluated by means of impersonal criteria, independently of their source
- Communism (communalism): scientific knowledge is the property of the entire human community, it is the common heritage of mankind (because it could only have been produced by using the work of predecessors)
- Disinterestedness: the scientist (and science as a whole) should have no interests riding on what will come out of scientific research
- Organized skepticism: temporary suspension of judgment, organized system of criticizing claims.

Upholding these (epistemic) values helps to realize the aim of science to produce reliable & trustworthy knowledge

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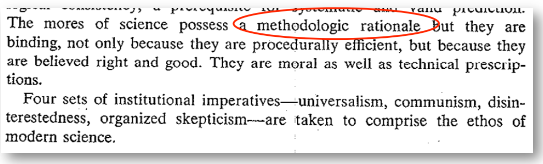
Robert Merton's proposal (2)

Merton on the professional ethos of science:



The mores of science possess a methodologic rationale but they are binding, not only because they are procedurally efficient, but because they are believed right and good. They are moral as well as technical prescriptions.

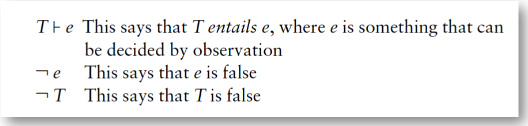
Four sets of institutional imperatives—universalism, communism, disinterestedness, organized skepticism—are taken to comprise the ethos of modern science.

(Merton, 1973: 270)

- Merton: methodological as well as moral prescriptions
- Content is purely methodological – it's about the increase of the efficiency of the process of knowledge production & of the quality of the product
- Acceptance is not moral either but rather psychological

The Duhem problem (1)

The simple view of falsification:



$T \vdash e$ This says that *T entails e*, where *e* is something that can be decided by observation

$\neg e$ This says that *e* is false

$\neg T$ This says that *T* is false

(Ladyman, p. 77)

- Take a hypothesis or theory *T*
- Deduce a prediction $T \rightarrow e$
- Test the prediction *e*
- If *e* is false, modus tollens tells us that *T* must be false
- If *e* is true, logic doesn't tell us anything about *T*

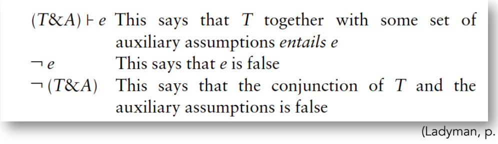
The problem: in practice we cannot deduce *e* from *T* alone, but from *T* plus multiple other claims about the world

The Duhem problem (2)

In order to deduce observable predictions from a theory we need

- claims about initial and boundary conditions (i.e., you need to specify the values of the relevant variables)
- other laws of nature, equations, etc.
- knowledge claims about the relevant measurement apparatuses that will be used in the observation
- etc.

The more complex view of falsification:



$(T\&A) \vdash e$ This says that T together with some set of auxiliary assumptions *entails e*

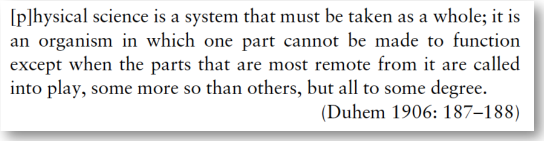
$\neg e$ This says that e is false

$\neg(T\&A)$ This says that the conjunction of T and the auxiliary assumptions is false

(Ladyman, p. 79)

The Duhem problem (3)

What is tested is a whole body of knowledge, not a single theory or hypothesis:



> [p]hysical science is a system that must be taken as a whole; it is an organism in which one part cannot be made to function except when the parts that are most remote from it are called into play, some more so than others, but all to some degree.
> (Duhem 1906: 187–188)

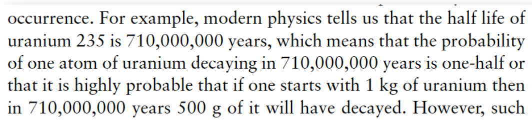
(Ladyman, p. 79)

Popper's answer:

Scientists agree on testing procedures, relevant background assumptions, etc. – that is, they create a context within which a theory can be tested (testing against the background of agreement in the relevant community)

Problems with falsificationism (1)

Probabilistic statements:



> occurrence. For example, modern physics tells us that the half life of uranium 235 is 710,000,000 years, which means that the probability of one atom of uranium decaying in 710,000,000 years is one-half or that it is highly probable that if one starts with 1 kg of uranium then in 710,000,000 years 500 g of it will have decayed. However, such

(Ladyman, p. 81)

- Such statements cannot be falsified as there is no determined outcome
- Improbable outcomes may still occur

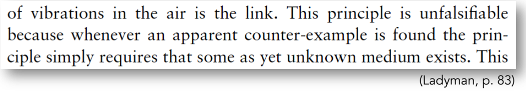
Existential statements:

- Statements like "There are black holes" cannot be falsified by our failure to find any black holes

Problems with falsificationism (2)

Scientific principles, such as:

- Conservation of energy
- Second law of thermodynamics (entropy)
- No action at a distance, a medium is required



> of vibrations in the air is the link. This principle is unfalsifiable because whenever an apparent counter-example is found the principle simply requires that some as yet unknown medium exists. This

(Ladyman, p. 83)

- "Occam's razor": do not assume more kinds of entities in your theory than you strictly need (ontological parsimony)
- Explanations must be unifying
- Simplicity: when faced with a choice, adopt the simplest theory

Some of these principles have scientific content, some methodological content

Problems with falsificationism (3)

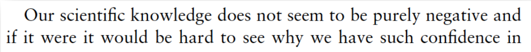
Falsification itself is not falsifiable:

- But it wasn't intended as a scientific theory anyway, but rather as a philosophical/logical theory of scientific method

Degrees of falsifiability:

- The more information a statement contains the more it can fail to hold – the more counterexamples are possible
- But the number of possible cases is always infinite for generalized statements
- So all theories and hypotheses are equally falsifiable

The problem of positive knowledge:

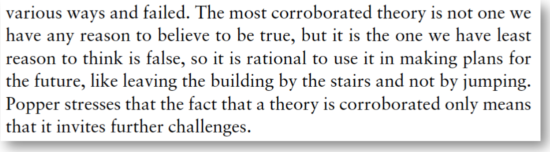


> Our scientific knowledge does not seem to be purely negative and if it were it would be hard to see why we have such confidence in certain scientifically informed beliefs. After all, it is because doctors

Positive knowledge

If falsifiability is all there is, what grounds do we have for accepting theories, hypotheses, etc. such that we can apply them in practice?

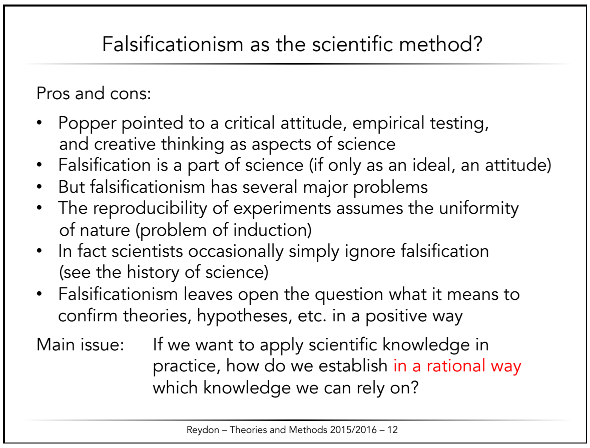
Corroboration:



> various ways and failed. The most corroborated theory is not one we have any reason to believe to be true, but it is the one we have least reason to think is false, so it is rational to use it in making plans for the future, like leaving the building by the stairs and not by jumping. Popper stresses that the fact that a theory is corroborated only means that it invites further challenges.

(Ladyman, p. 87)

- The more corroborated a theory is, the more rational reasons we have to accept it
- But such acceptance is not well-founded – life's a gamble



Falsificationism as the scientific method?

Pros and cons:

- Popper pointed to a critical attitude, empirical testing, and creative thinking as aspects of science
- Falsification is a part of science (if only as an ideal, an attitude)
- But falsificationism has several major problems
- The reproducibility of experiments assumes the uniformity of nature (problem of induction)
- In fact scientists occasionally simply ignore falsification (see the history of science)
- Falsificationism leaves open the question what it means to confirm theories, hypotheses, etc. in a positive way

Main issue: If we want to apply scientific knowledge in practice, how do we establish in a rational way which knowledge we can rely on?

Lecture #7 (Nov. 30, 2015)

Text: Ladyman, *Understanding Philosophy of Science*, Chapter 4

Where to get theories & what to do with them?

Two contexts:

- Context of discovery:
  - Discovery of new knowledge claims, generating hypotheses, claims, etc.
  - Bacon: the production of theories and claims is a mechanical process (systematizing cases in tables, comparison, induction)
  - Any method is allowed: induction, dreaming up theories, speculation, personal preferences, …
- Context of justification:
  - Justifying, i.e., trying to support knowledge claims, hypotheses , theories, etc.
  - Testing: falsification, experimentation, …
  - Testing is susceptible to logical / methodological analysis

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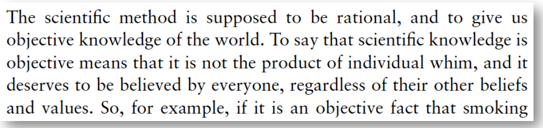
The scientific method



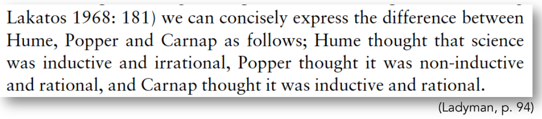
The scientific method is supposed to be rational, and to give us objective knowledge of the world. To say that scientific knowledge is objective means that it is not the product of individual whim, and it deserves to be believed by everyone, regardless of their other beliefs and values. So, for example, if it is an objective fact that smoking

(Ladyman, p. 93)

Scientific method:

- Rational way of justifying knowledge, such that it can be accepted by everyone independently of background
- Naïve inductivism (Bacon) – induction in both contexts
- Falsificationism (Popper) – context of justification only
- Sophisticated inductivism: induction rescued by applying probability theory, assuming a pragmatic attitude, etc.
- "The context of discovery is outside the domain of rationality"

How rational is science?



Lakatos 1968: 181) we can concisely express the difference between Hume, Popper and Carnap as follows; Hume thought that science was inductive and irrational, Popper thought it was non-inductive and rational, and Carnap thought it was inductive and rational.

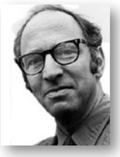
(Ladyman, p. 94)

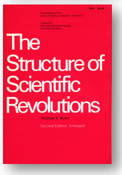
Today: science is non-inductive and irrational (in part)

This view opposes much of the received view:

- Popper: the problem of induction shows that theory confirmation is impossible
- Logical empiricism: it shows we need better logic
- Science is cumulative (scientific progress)
- Science is unified (single methodological core, reduction of other sciences to fundamental physics)
- Fundamental epistemological distinction btw. the two contexts
- Search for a logic of confirmation

Thomas Kuhn





Thomas Kuhn:

- Born 1922 in Cincinnati, died 1996 in Cambridge (MA)
- Historian of science who included a lot of philosophy of science in his historical work
- The famous book: *The Structure of Scientific Revolutions* (1962, 2nd ed. 1970)
- Larger revolutions in science do not fit the picture of science drawn by inductivism or falsificationism – what happened in such periods is quite different & more complex
- Key term: "paradigm"
- Science proceeds by paradigm changes in periods of scientific revolution – by bursts rather than by gradual cumulative progression

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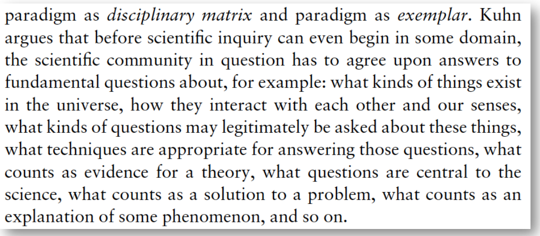
Paradigms (1)



paradigm as *disciplinary matrix* and paradigm as *exemplar*. Kuhn argues that before scientific inquiry can even begin in some domain, the scientific community in question has to agree upon answers to fundamental questions about, for example: what kinds of things exist in the universe, how they interact with each other and our senses, what kinds of questions may legitimately be asked about these things, what techniques are appropriate for answering those questions, what counts as evidence for a theory, what questions are central to the science, what counts as a solution to a problem, what counts as an explanation of some phenomenon, and so on.

(Ladyman, pp. 98)

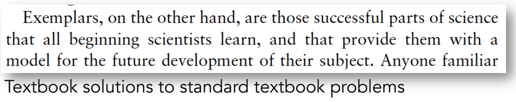
- No unequivocally defined term
- "This is a paradigmatic example of …"
- Two key notions: - Paradigm as disciplinary matrix
  - Paradigm as exemplar

Paradigms (2)

Disciplinary matrix:

- Set of answers to the sorts of questions on the preceding slide
- Sometimes explicit, sometimes implicit background framework of the work done in a particular field of science
- Contains ways of doing research, practical skills, preferred types of explanation, preferred solutions to core problems in the field, shared values, etc.
- Scientists in a particular field become embedded in the current paradigm in their training

Exemplar:

- 
  Exemplars, on the other hand, are those successful parts of science that all beginning scientists learn, and that provide them with a model for the future development of their subject. Anyone familiar
- Textbook solutions to standard textbook problems

Paradigms (3)

Normal science:

- Research that is conducted within the established paradigm
- Work is aimed at extending and strengthening the paradigm
- E.g.: gathering of new observations to fit within the available body of knowledge, solving minor problems that occur within the accepted theory, applying established theories and models to new cases that are similar to cases that have already been studied (do you get the same curve with a slightly different sample?), etc.
- Consider: trying to find the Higgs boson, trying to produce heavy elements, sequencing the genome of a new model organism, etc.
- "Puzzle solving" under clearly set rules – a solution is expected
- The fundamental principles, theories, techniques, etc. are not questioned but taken as the basis of further work

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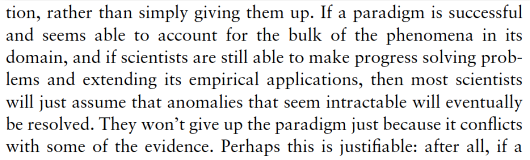
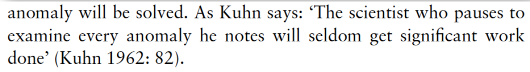
Paradigms (4)

Anomalies are instances of falsification:



tion, rather than simply giving them up. If a paradigm is successful and seems able to account for the bulk of the phenomena in its domain, and if scientists are still able to make progress solving problems and extending its empirical applications, then most scientists will just assume that anomalies that seem intractable will eventually be resolved. They won't give up the paradigm just because it conflicts with some of the evidence. Perhaps this is justifiable: after all, if a



anomaly will be solved. As Kuhn says: 'The scientist who pauses to examine every anomaly he notes will seldom get significant work done' (Kuhn 1962: 82).

(Ladyman, p. 101)

- Recall the Duhem problem – it's not clear what is falsified
- Sticking to the paradigm isn't entirely rational

Paradigms (5)

Anomalies, crises and revolutions:

- Serious anomalies might occur and accumulate over time, causing difficulties for the established paradigm
- Some scientists might begin to reject the paradigm and search for a new one
- Crises occur infrequently – a paradigm only becomes established when it is able to cover most of the relevant phenomena in a field, i.e., when it has already been tested well
- Individual scientists cannot easily question the dominant paradigm – otherwise they risk their careers and reputation
- Occasionally, a scientific revolution or paradigm shift occurs
- Involves a new perspective of the world, as well as the complete replacement of the old paradigm
- Note that individual elements may be retained and incorporated into the new paradigm

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Scientific revolutions (1)

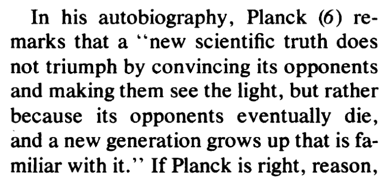
What is a scientific revolution?

- Transition from one paradigm to a new one
- E.g., the Copernican revolution, the phlogiston-oxygen transition, the Darwinian revolution, the transition from classical physics to quantum physics, the transition to relativistic physics, …
- Radical breaks instead of steady, cumulative growth of knowledge – radical shift to a new way of thinking about the world (Ladyman, p. 103)
- A viable new way of thinking must be available before any transition can be made
- After a revolution there are novel problems to work on, and old problems may be regarded irrelevant rather than solved
- Old paradigm → accumulating anomalies → crisis → new paradigm
  ↑_______________________________ paradigm

Scientific revolutions (2)

Revolutions occur at a social level, the level of the community:

- "Planck's Principle":

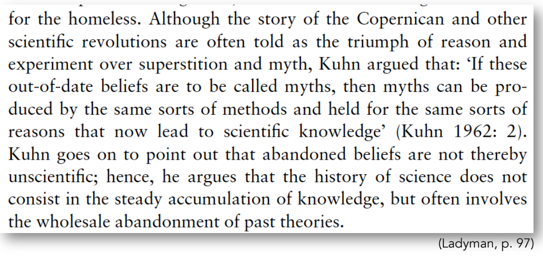


In his autobiography, Planck (*6*) remarks that a "new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." If Planck is right, reason,

(Hull, Tessner & Diamond, 1978: 718)

- It's often not about individuals being convinced one by one
- Acceptance of a paradigm also depends on a person's values, views, social background, psychology, etc.

Scientific revolutions (3)



for the homeless. Although the story of the Copernican and other scientific revolutions are often told as the triumph of reason and experiment over superstition and myth, Kuhn argued that: 'If these out-of-date beliefs are to be called myths, then myths can be produced by the same sorts of methods and held for the same sorts of reasons that now lead to scientific knowledge' (Kuhn 1962: 2). Kuhn goes on to point out that abandoned beliefs are not thereby unscientific; hence, he argues that the history of science does not consist in the steady accumulation of knowledge, but often involves the wholesale abandonment of past theories.

(Ladyman, p. 97)

- Duhem problem: logic alone does not tell us which element of the theoretical system is wrong
- Therefore, there is always a non-logical component of theory choice

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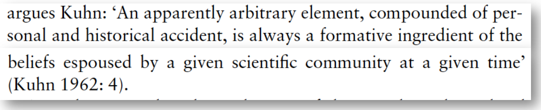
Scientific revolutions (4)

Historical accidents & personal preferences play a key role in scientific revolutions:



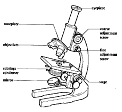
argues Kuhn: 'An apparently arbitrary element, compounded of personal and historical accident, is always a formative ingredient of the beliefs espoused by a given scientific community at a given time' (Kuhn 1962: 4).

(Ladyman, pp. 97-98)

Revolutions and the scientific method:

- Proponents of a clear scientific method claim that theory choice is fully rational, methodical
- The method can be used to develop theories, confirm them, and choose between alternatives (which is better confirmed?)
- We have seen that it doesn't work that way

Theory-ladenness of observation (1)

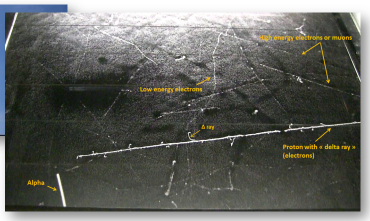


A paradigm is the theoretical framework within which you observe the world

- Bacon's ideal: simply observe nature, systematize observations using comparative tables, and formulate general principles by means of induction
- The problem: for observation you need concepts (you cannot observe swans without having the concept 'swan')
- In science, observations are made in the context of a theory (the theory tells you what to look for)
- Observations are made with equipment that scientists have to learn to use – you cannot "just look" through a microscope, but have to learn what to look for and to interpret what you see
- Failures to see phenomena before they were predicted by theory (e.g., positrons in cloud chambers – Ladyman, p.112)
- Scientists in different paradigms "live in different worlds"

Theory-ladenness of observation (2)

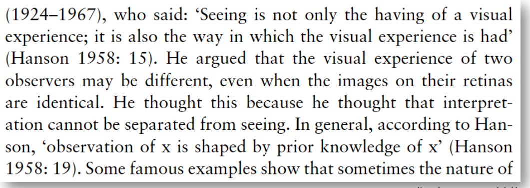
Continuum between observation and inference:



Picture caption:

"This rare picture show the 4 types of charged particles that we can detect in a cloud chamber: alpha, proton, electron and muons (probably). Picture taken at the Pic du Midi at 2877m in a Phywe PJ45 diffusion cloud chamber. Size of the interaction surface is 45x45 cm" (www.cloudylabs.fr)

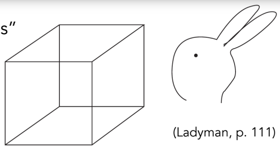
Theory-ladenness of observation (3)



(1924–1967), who said: 'Seeing is not only the having of a visual experience; it is also the way in which the visual experience is had' (Hanson 1958: 15). He argued that the visual experience of two observers may be different, even when the images on their retinas are identical. He thought this because he thought that interpretation cannot be separated from seeing. In general, according to Hanson, 'observation of x is shaped by prior knowledge of x' (Hanson 1958: 19). Some famous examples show that sometimes the nature of

(Ladyman, p. 111)

"Gestalt shifts" in seeing:



(Ladyman, p. 111)

Lecture #8 (Dec. 7, 2015)

Text: Ladyman, *Understanding Philosophy of Science*, Chapter 7

Today's topic & the next two weeks

So far:

- The scientific method
  - Supposed to distinguish science from non-science
  - Supposed to be a tool to produce theories, hypotheses, …
  - Supposed to be a tool to justify theories, hypotheses, …
- Induction (various kinds)
- Falsification
- Contexts of discovery and justification
- Paradigms and scientific revolutions

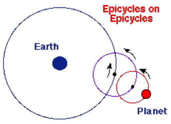
The rest of this course:

- What does it mean to explain a phenomenon?
- Research ethics and good scientific practice
- Values and the aims of science
- Your presentations or written assignments

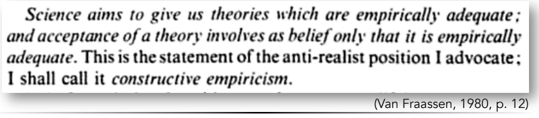
Explanation & description (1)

Explanation is one of the principal aims of science:

- Description of a phenomenon vs. explanation of a phenomenon – what is the difference?
- "To save the phenomena" – adapting a theory / introducing a new one while continuing to describe the phenomena adequately
- Ptolemy's (~100 A.D.) astronomical model (assumption of epicycles upon epicycles)
- Bas van Fraassen's constructive empiricism:



http://csep10.phys.utk.edu



> *Science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate.* This is the statement of the anti-realist position I advocate; I shall call it *constructive empiricism*.

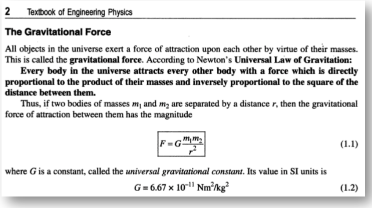
(Van Fraassen, 1980, p. 12)

Explanation & description (2)

- Explanation is supposed to tell us why things happen as they do, description only tells us how they happen
- Nomic explanation (explanation using laws):
  - Laws of nature constitute the basis of explanation
  - Laws of nature necessitate certain events – a phenomenon had to happen in the way that it did because of the relevant laws of nature
  - Laws of nature "rule the world"
- Recall Francis Bacon's ideal: find the deepest laws of nature by empirical observation, experiments, comparative tables, induction
- Some problems: What is a law of nature? What distinguishes a "good" law of nature from a mere empirical generalization How do we know we've actually found a "good" law of nature?

Kinds of explanation (1)

- Nomic explanation: bringing a phenomenon under a law of nature
- What does the difference btw. explanation & prediction consist in?



2 Textbook of Engineering Physics

The Gravitational Force

All objects in the universe exert a force of attraction upon each other by virtue of their masses. This is called the **gravitational force**. According to Newton's **Universal Law of Gravitation:**

Every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Thus, if two bodies of masses m_1 and m_2 are separated by a distance r, then the gravitational force of attraction between them has the magnitude

$$\boxed{F = G\frac{m_1 m_2}{r^2}} \quad (1.1)$$

where G is a constant, called the *universal gravitational constant*. Its value in SI units is

$$G = 6.67 \times 10^{-11}\ \mathrm{Nm^2/kg^2} \quad (1.2)$$

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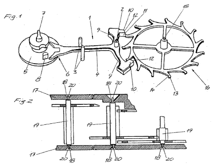
- Evolutionary explanation: specifies selective conditions at a particular stage of evolution – story telling
- Functional explanation: a property is the way it is because it has to fulfill a particular function – intentional or natural design

Kinds of explanation (2)

- Mechanistic explanation: specifies how the phenomenon follows from the interactions of the parts of a mechanism
- Explains by specifying the parts of the system + the ways they influence each other

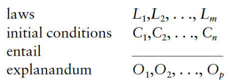


- Historical explanation:
- Tells a story of events of which one led to the next, to the next, etc.
- Explains by highlighting unique historical events
- "How possibly" explanations: explain the possibility of an event, not its actual occurrence
- How could the field player have caught the ball? (Dray, 1957)

www.chron.com

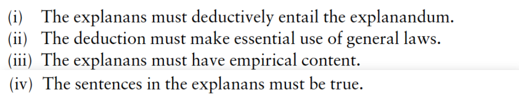
The covering law model

- Laws of nature represent causes of the phenomena
- To explain a phenomenon (the *explanandum*) is to show how it logically follows from one or more laws of nature plus a set of initial conditions
- *Explanans*: that which "does the explaining"
- An explanation is an argument with the logical form of deduction:



laws	$L_1, L_2, \ldots, L_m$
initial conditions	$C_1, C_2, \ldots, C_n$
entail	
explanandum	$O_1, O_2, \ldots, O_p$

(Ladyman, p. 201)

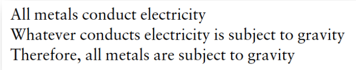


(i) The explanans must deductively entail the explanandum.
(ii) The deduction must make essential use of general laws.
(iii) The explanans must have empirical content.
(iv) The sentences in the explanans must be true.

The covering law model – problems (1)

Irrelevance problem:

Some laws might be irrelevant to the phenomenon we want to explain, even if they yield deductively valid arguments



All metals conduct electricity
Whatever conducts electricity is subject to gravity
Therefore, all metals are subject to gravity

(Ladyman, p. 203)

Pre-emption problem:

The explanandum could have been explained by the explanans but in the case under consideration the event was caused by something else

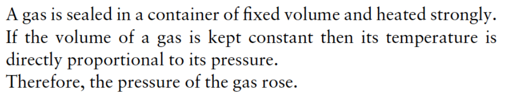
Overdetermination problem:

Multiple causal conditions are realized, each of which alone would have been sufficient for the explanandum to occur

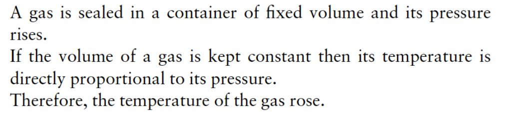
The covering law model – problems (2)

Symmetry problem:

Many laws are laws of co-existence, e.g. $pV = nRT$:



A gas is sealed in a container of fixed volume and heated strongly.
If the volume of a gas is kept constant then its temperature is directly proportional to its pressure.
Therefore, the pressure of the gas rose.



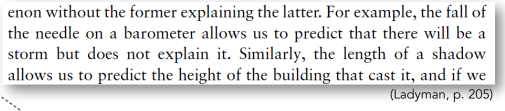
A gas is sealed in a container of fixed volume and its pressure rises.
If the volume of a gas is kept constant then its temperature is directly proportional to its pressure.
Therefore, the temperature of the gas rose.

(Ladyman, pp. 204-205)

The covering law model – problems (3)

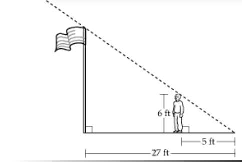
Prediction vs. explanation:

Logically there is no difference between explanation and prediction (Hempel's thesis of structural identity)



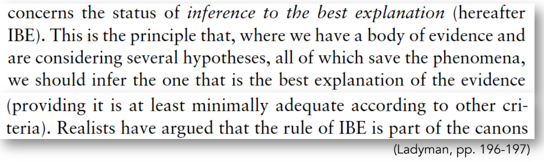
enon without the former explaining the latter. For example, the fall of the needle on a barometer allows us to predict that there will be a storm but does not explain it. Similarly, the length of a shadow allows us to predict the height of the building that cast it, and if we

(Ladyman, p. 205)



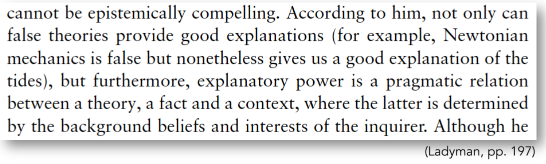
Flagpole problem: We can calculate all kinds of unknown values from known values (e.g., height of the pole from the length of the shadow + angle), but not all of these are causally explanatory

Inference to the best explanation (1)



concerns the status of *inference to the best explanation* (hereafter IBE). This is the principle that, where we have a body of evidence and are considering several hypotheses, all of which save the phenomena, we should infer the one that is the best explanation of the evidence (providing it is at least minimally adequate according to other criteria). Realists have argued that the rule of IBE is part of the canons

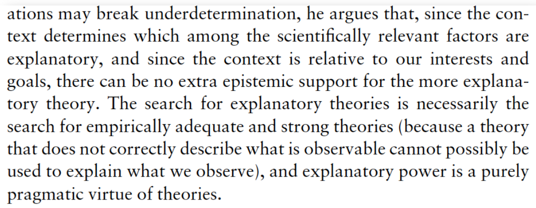
(Ladyman, pp. 196-197)



cannot be epistemically compelling. According to him, not only can false theories provide good explanations (for example, Newtonian mechanics is false but nonetheless gives us a good explanation of the tides), but furthermore, explanatory power is a pragmatic relation between a theory, a fact and a context, where the latter is determined by the background beliefs and interests of the inquirer. Although he

(Ladyman, pp. 197)

Inference to the best explanation (2)



ations may break underdetermination, he argues that, since the context determines which among the scientifically relevant factors are explanatory, and since the context is relative to our interests and goals, there can be no extra epistemic support for the more explanatory theory. The search for explanatory theories is necessarily the search for empirically adequate and strong theories (because a theory that does not correctly describe what is observable cannot possibly be used to explain what we observe), and explanatory power is a purely pragmatic virtue of theories.

(Ladyman, pp. 197)

Inference to the best explanation:

- Rule for choosing between competing explanations
- The best explanation is the one that best fits the rest of our knowledge, our beliefs, etc. and the general context

Lecture #8 (Dec. 14, 2015)

Texts: Barker & Kitcher, *Philosophy of Science*; ESF/ALLEA, *Code of Conduct*

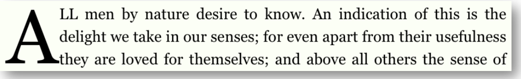
Today's topic: values and good scientific practice

- So far: focus on the scientific method, scientific inferences, rationality, theory change, progress in science
- Philosophy of science has neglected the question of values in science for the larger part of the 20th century
- Two traditional ideals
  - Value-free science (science is objective, neutral, deals with hard facts, has nothing to do with value judgments, normativity, political views, etc.)
  - Autonomous science (science should be free of external control, the scientific community should be free to pursue any question in any way it sees fit)
- Newer trend in philosophy of science (late 20th century): values come into play in theory choice, choice of research topics and projects, governance of science, etc.

Aims of science

Three views of the aims of science:

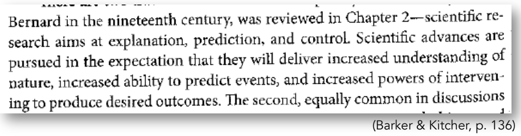
- Satisfying curiosity (as an element of human nature)



ALL men by nature desire to know. An indication of this is the delight we take in our senses; for even apart from their usefulness they are loved for themselves; and above all others the sense of

(Aristotle, *Metaphysics A*, opening sentences)

- Explanation, prediction and control



Bernard in the nineteenth century, was reviewed in Chapter 2—scientific research aims at explanation, prediction, and control. Scientific advances are pursued in the expectation that they will deliver increased understanding of nature, increased ability to predict events, and increased powers of intervening to produce desired outcomes. The second, equally common in discussions

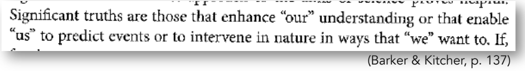
(Barker & Kitcher, p. 136)

- Truth? Problematic notion!

Truth as an aim of science

The "whole truth" about nature is unattainable:

- When is a statement true? (Esp. general claims, laws of nature)
- There are too many truths to be known – too many tiny details about what the world is like
- Many truths do not matter to you or even to anyone
- Some truths are significant, others aren't
- Set the aim of science as obtaining significant truths about the world, rather than simply truths about the world (let alone the whole truth)
- What makes a truth significant?

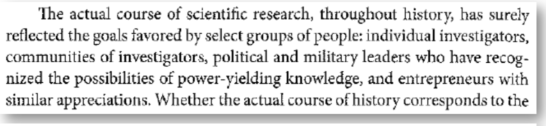


Significant truths are those that enhance "our" understanding or that enable "us" to predict events or to intervene in nature in ways that "we" want to. If,

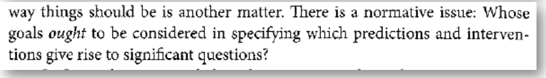
(Barker & Kitcher, p. 137)

- Back to our practical aims: controlling nature, improving our lives (cf. Francis Bacon)

Whose interests? (1)

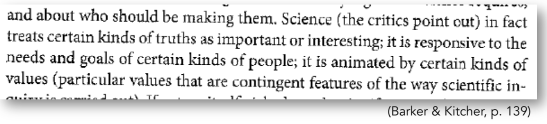


The actual course of scientific research, throughout history, has surely reflected the goals favored by select groups of people: individual investigators, communities of investigators, political and military leaders who have recognized the possibilities of power-yielding knowledge, and entrepreneurs with similar appreciations. Whether the actual course of history corresponds to the



way things should be is another matter. There is a normative issue: Whose goals *ought* to be considered in specifying which predictions and interventions give rise to significant questions?

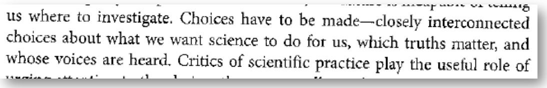
(Barker & Kitcher, p. 138)



and about who should be making them. Science (the critics point out) in fact treats certain kinds of truths as important or interesting; it is responsive to the needs and goals of certain kinds of people; it is animated by certain kinds of values (particular values that are contingent features of the way scientific in-

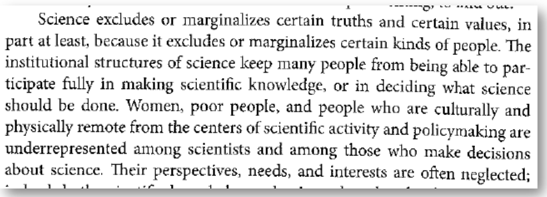
(Barker & Kitcher, p. 139)

Whose interests? (2)



us where to investigate. Choices have to be made—closely interconnected choices about what we want science to do for us, which truths matter, and whose voices are heard. Critics of scientific practice play the useful role of

(Barker & Kitcher, p. 139)



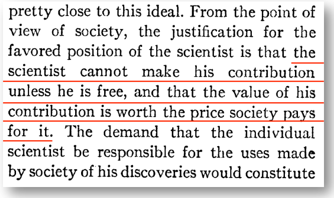
Science excludes or marginalizes certain truths and certain values, in part at least, because it excludes or marginalizes certain kinds of people. The institutional structures of science keep many people from being able to participate fully in making scientific knowledge, or in deciding what science should be done. Women, poor people, and people who are culturally and physically remote from the centers of scientific activity and policymaking are underrepresented among scientists and among those who make decisions about science. Their perspectives, needs, and interests are often neglected;

(Barker & Kitcher, p. 139)

Whose interests? (3)

Who should decide about which truths (research questions) to pursue – " about the direction that scientific inquiry takes? (p. 141)

- One the one hand science should be responsive to the needs of the public
- On the other hand science is autonomous, scientists should be free to pursue any questions they deem interesting


pretty close to this ideal. From the point of view of society, the justification for the favored position of the scientist is that the scientist cannot make his contribution unless he is free, and that the value of his contribution is worth the price society pays for it. The demand that the individual scientist be responsible for the uses made by society of his discoveries would constitute

(Percy Bridgman, *Sci. Monthly* 65, 1947)

Values in science?

The ideal of value-free science: ideal of objectivity, value-neutrality, unbiasedness, etc. seem part of responsible science

Two kinds of values (among which there may be conflicts):

- Epistemic values: values relating directly to knowledge, knowledge production & scientific reasoning
- E.g.: simplicity, explanatory power, explanatory scope, relevance of evidence, etc.
- Non-epistemic values: values that do not or only indirectly relate to the process of knowledge production
- These are social, cultural, personal, religious, etc. values.

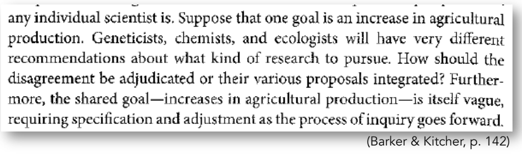
Value-free science means science that is free from non-epistemic values (epistemic values are part and parcel of science)

→ Should science be value-free in this sense? Why? Why not?

How to decide? (1)

The decision process involves different groups of people:

- Scientists are the experts for the scientific content
- But scientists from different fields may well disagree

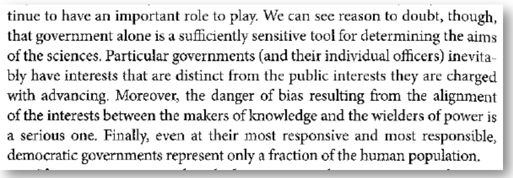

any individual scientist is. Suppose that one goal is an increase in agricultural production. Geneticists, chemists, and ecologists will have very different recommendations about what kind of research to pursue. How should the disagreement be adjudicated or their various proposals integrated? Furthermore, the shared goal—increases in agricultural production—is itself vague, requiring specification and adjustment as the process of inquiry goes forward.

(Barker & Kitcher, p. 142)

- The public (politicians, interest groups, affected parts of the population, etc.) needs to be involved
  - at the start of a project (yes-or-no decision)
  - during the project (to weigh new options as they emerge)

How to decide? (2)

In a representative democracy, shouldn't it be the role of the government to decide?


tinue to have an important role to play. We can see reason to doubt, though, that government alone is a sufficiently sensitive tool for determining the aims of the sciences. Particular governments (and their individual officers) inevitably have interests that are distinct from the public interests they are charged with advancing. Moreover, the danger of bias resulting from the alignment of the interests between the makers of knowledge and the wielders of power is a serious one. Finally, even at their most responsive and most responsible, democratic governments represent only a fraction of the human population.

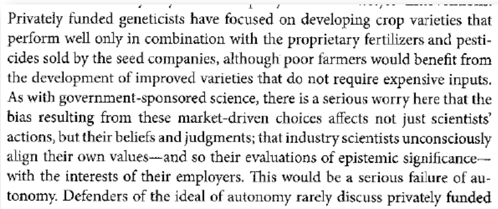
(Barker & Kitcher, p. 142)

If not the government, then perhaps the free market?

- Patenting hampers the free flow of knowledge
- Wrong incentive to pursue research (maximizing investors' profits)

How to decide? (3)

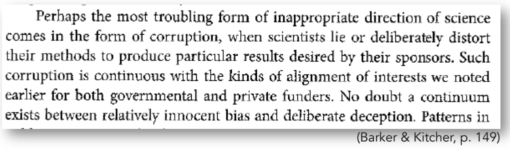
If not the government, then perhaps the free market?


Privately funded geneticists have focused on developing crop varieties that perform well only in combination with the proprietary fertilizers and pesticides sold by the seed companies, although poor farmers would benefit from the development of improved varieties that do not require expensive inputs. As with government-sponsored science, there is a serious worry here that the bias resulting from these market-driven choices affects not just scientists' actions, but their beliefs and judgments; that industry scientists unconsciously align their own values—and so their evaluations of epistemic significance—with the interests of their employers. This would be a serious failure of autonomy. Defenders of the ideal of autonomy rarely discuss privately funded

(Barker & Kitcher, p. 149)

How to decide? (4)

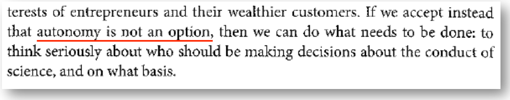
If not the government, then perhaps the free market?


Perhaps the most troubling form of inappropriate direction of science comes in the form of corruption, when scientists lie or deliberately distort their methods to produce particular results desired by their sponsors. Such corruption is continuous with the kinds of alignment of interests we noted earlier for both governmental and private funders. No doubt a continuum exists between relatively innocent bias and deliberate deception. Patterns in

(Barker & Kitcher, p. 149)

Neither the scientific community alone, nor governments, nor the free market seem able to "govern" science by itself

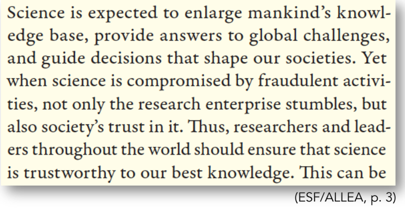
???


terests of entrepreneurs and their wealthier customers. If we accept instead that autonomy is not an option, then we can do what needs to be done: to think seriously about who should be making decisions about the conduct of science, and on what basis.

Self-governance in science (1)

Self-governance with respect to which research projects and questions should be pursed? → next week

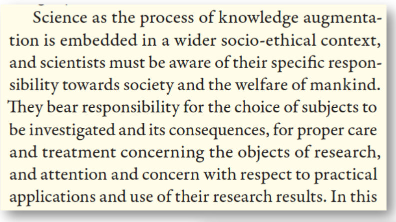
Self-governance with respect to how science is conducted



Science is expected to enlarge mankind's knowledge base, provide answers to global challenges, and guide decisions that shape our societies. Yet when science is compromised by fraudulent activities, not only the research enterprise stumbles, but also society's trust in it. Thus, researchers and leaders throughout the world should ensure that science is trustworthy to our best knowledge. This can be

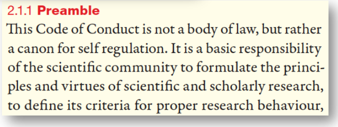
(ESF/ALLEA, p. 3)

Self-governance in science (2)



Science as the process of knowledge augmentation is embedded in a wider socio-ethical context, and scientists must be aware of their specific responsibility towards society and the welfare of mankind. They bear responsibility for the choice of subjects to be investigated and its consequences, for proper care and treatment concerning the objects of research, and attention and concern with respect to practical applications and use of their research results. In this

(ESF/ALLEA, p. 8)

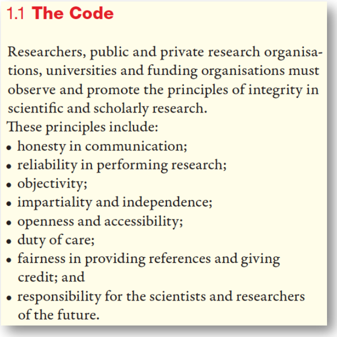


2.1.1 Preamble

This Code of Conduct is not a body of law, but rather a canon for self regulation. It is a basic responsibility of the scientific community to formulate the principles and virtues of scientific and scholarly research, to define its criteria for proper research behaviour,

Self-governance in science (3)

Good scientific practice:



1.1 The Code

Researchers, public and private research organisations, universities and funding organisations must observe and promote the principles of integrity in scientific and scholarly research.

These principles include:

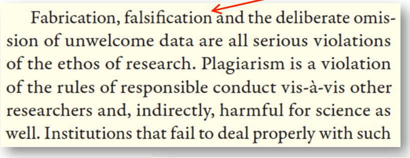
- honesty in communication;
- reliability in performing research;
- objectivity;
- impartiality and independence;
- openness and accessibility;
- duty of care;
- fairness in providing references and giving credit; and
- responsibility for the scientists and researchers of the future.

(ESF/ALLEA, p. 5)

Self-governance in science (4)

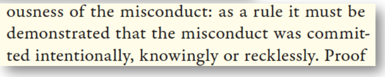
Scientific misconduct:

Note: not Popper's!



Fabrication, falsification and the deliberate omission of unwelcome data are all serious violations of the ethos of research. Plagiarism is a violation of the rules of responsible conduct vis-à-vis other researchers and, indirectly, harmful for science as well. Institutions that fail to deal properly with such

(ESF/ALLEA, p. 5)



ousness of the misconduct: as a rule it must be demonstrated that the misconduct was committed intentionally, knowingly or recklessly. Proof

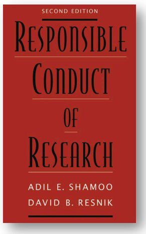
- "FFP" definition of scientific misconduct
- FFP is the "severe end" of the spectrum, leading to investigations by university committees, etc.

Responsibility of scientists

The responsibility of scientists with respect to society is multi-faceted:

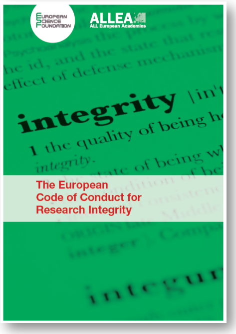
"Scientists have an obligation to benefit society and avoid causing harm to people, communities, and the environment. Scientists must also be accountable to the public. Scientists can fulfill their social responsibilities in many different ways, such as conducting useful research, educating the public about science and its social implications, providing expert testimony and advice on scientific issues, or engaging in policy debates concerning issues related to the applications or implications of science and technology …"

(Shamoo & Resnik, 2009: 6)



European Code of Conduct

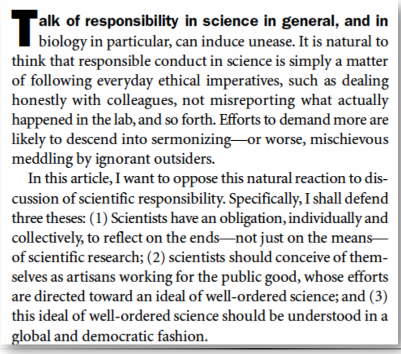
Read this for yourselves:



Lecture #10 (Dec. 21, 2015)

Texts: Barker & Kitcher, *Philosophy of Science*; Kitcher, *Responsible Biology*

Responsibility in science (1)

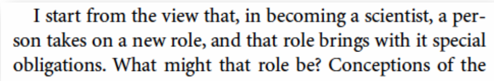


Talk of responsibility in science in general, and in biology in particular, can induce unease. It is natural to think that responsible conduct in science is simply a matter of following everyday ethical imperatives, such as dealing honestly with colleagues, not misreporting what actually happened in the lab, and so forth. Efforts to demand more are likely to descend into sermonizing—or worse, mischievous meddling by ignorant outsiders.

In this article, I want to oppose this natural reaction to discussion of scientific responsibility. Specifically, I shall defend three theses: (1) Scientists have an obligation, individually and collectively, to reflect on the ends—not just on the means—of scientific research; (2) scientists should conceive of themselves as artisans working for the public good, whose efforts are directed toward an ideal of well-ordered science; and (3) this ideal of well-ordered science should be understood in a global and democratic fashion.

(Kitcher, p. 331)

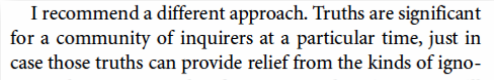
Responsibility in science (2)



I start from the view that, in becoming a scientist, a person takes on a new role, and that role brings with it special obligations. What might that role be? Conceptions of the

(Kitcher, p. 331)

- Scientists as a "secular priesthood" in the service of truth, the whole truth, and nothing but the truth
- But the whole truth cannot be achieved, instead we select truths that we find important:



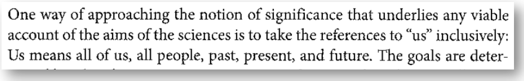
I recommend a different approach. Truths are significant for a community of inquirers at a particular time, just in case those truths can provide relief from the kinds of ignorance that are properly of concern at that time. You will

(Kitcher, p. 331)

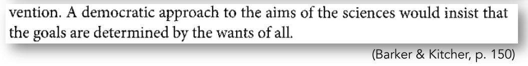
Whose interests? Who decides?

Whose interests should be served?

- Recall Bacon's ideal of science for the improvement of life
- Inclusive ideal:



One way of approaching the notion of significance that underlies any viable account of the aims of the sciences is to take the references to "us" inclusively: Us means all of us, all people, past, present, and future. The goals are deter-



vention. A democratic approach to the aims of the sciences would insist that the goals are determined by the wants of all.

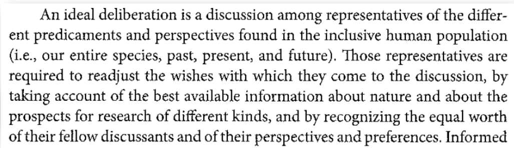
(Barker & Kitcher, p. 150)

- Vulgar democracy:
  - Everyone gets to vote on which lines of research to pursue
  - "Dictatorship of the uninformed", "tyranny of ignorance"
  - Often potential uses cannot be predicted

Well-ordered science (1)

Well-ordered science as a form of partial scientific self-governance

- Ideal deliberation:



An ideal deliberation is a discussion among representatives of the different predicaments and perspectives found in the inclusive human population (i.e., our entire species, past, present, and future). Those representatives are required to readjust the wishes with which they come to the discussion, by taking account of the best available information about nature and about the prospects for research of different kinds, and by recognizing the equal worth of their fellow discussants and of their perspectives and preferences. Informed

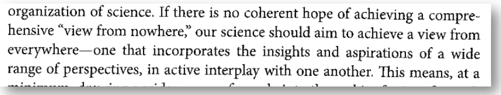
(Barker & Kitcher, p. 151)

- The idea is to
  - Introduce democratic values into science
  - Include all interests of all parties in society
  - Consider future generations as well as present ones
  - Achieve an optimally informed debate

Well-ordered science (2)

Two-way system: well-ordered science serves to

- make sure scientific research serves the interests of all members of society in the best possible way:



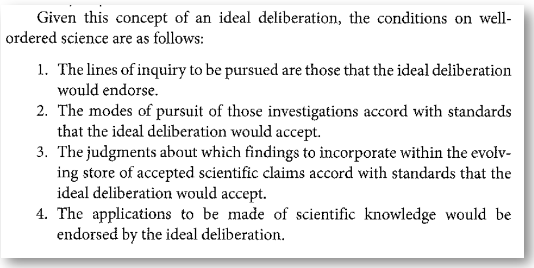
organization of science. If there is no coherent hope of achieving a comprehensive "view from nowhere," our science should aim to achieve a view from everywhere—one that incorporates the insights and aspirations of a wide range of perspectives, in active interplay with one another. This means, at a

(Barker & Kitcher, p. 161)

- all interests are weighed and flow into decisions about which lines of research to pursue,
- as well as into decisions on how results from scientific investigations are to be interpreted for policy use

Requirement: information of the public (science journalism, science education, engagement of scientists)

Well-ordered science (3)



Given this concept of an ideal deliberation, the conditions on well-ordered science are as follows:

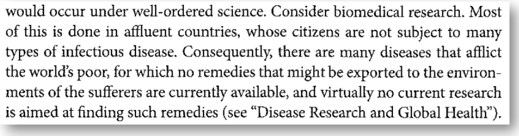
1. The lines of inquiry to be pursued are those that the ideal deliberation would endorse.
2. The modes of pursuit of those investigations accord with standards that the ideal deliberation would accept.
3. The judgments about which findings to incorporate within the evolving store of accepted scientific claims accord with standards that the ideal deliberation would accept.
4. The applications to be made of scientific knowledge would be endorsed by the ideal deliberation.

(Barker & Kitcher, p. 151)

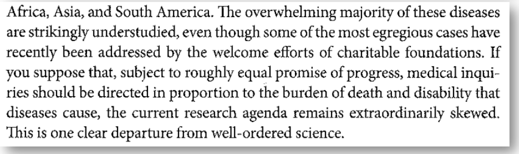
- Note that this ideal deliberation (optimal information & representation) implies an unachievable ideal

Example: investigating diseases

- Understudied diseases:



would occur under well-ordered science. Consider biomedical research. Most of this is done in affluent countries, whose citizens are not subject to many types of infectious disease. Consequently, there are many diseases that afflict the world's poor, for which no remedies that might be exported to the environments of the sufferers are currently available, and virtually no current research is aimed at finding such remedies (see "Disease Research and Global Health").

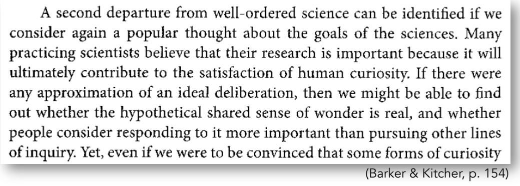


Africa, Asia, and South America. The overwhelming majority of these diseases are strikingly understudied, even though some of the most egregious cases have recently been addressed by the welcome efforts of charitable foundations. If you suppose that, subject to roughly equal promise of progress, medical inquiries should be directed in proportion to the burden of death and disability that diseases cause, the current research agenda remains extraordinarily skewed. This is one clear departure from well-ordered science.

(Barker & Kitcher, p. 153)

The aims of science, again

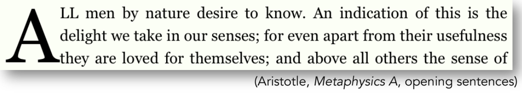
- Satisfying curiosity:



A second departure from well-ordered science can be identified if we consider again a popular thought about the goals of the sciences. Many practicing scientists believe that their research is important because it will ultimately contribute to the satisfaction of human curiosity. If there were any approximation of an ideal deliberation, then we might be able to find out whether the hypothetical shared sense of wonder is real, and whether people consider responding to it more important than pursuing other lines of inquiry. Yet, even if we were to be convinced that some forms of curiosity

(Barker & Kitcher, p. 154)

- Back to Aristotle?

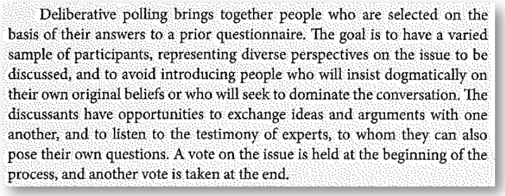


ALL men by nature desire to know. An indication of this is the delight we take in our senses; for even apart from their usefulness they are loved for themselves; and above all others the sense of

(Aristotle, *Metaphysics A*, opening sentences)

How to realize well-ordered science

- Vulgar democracy
- Parliamentary control / governmental control
- Polls on proposed research projects, public debates
- Deliberative polling:



Deliberative polling brings together people who are selected on the basis of their answers to a prior questionnaire. The goal is to have a varied sample of participants, representing diverse perspectives on the issue to be discussed, and to avoid introducing people who will insist dogmatically on their own original beliefs or who will seek to dominate the conversation. The discussants have opportunities to exchange ideas and arguments with one another, and to listen to the testimony of experts, to whom they can also pose their own questions. A vote on the issue is held at the beginning of the process, and another vote is taken at the end.

(Barker & Kitcher, p. 156)

- Scientific self-governance (in-house deliberation)

Examples of exam questions

Questions should be answered with 5-10 sentences each. There is no need to go into great detail, mention names or dates, write long explanations or arguments, etc. But you must give your own view and support it with a few arguments.

- Explain the standard model of scientific explanation. Do you think it is a good model of what scientific explanations consist in? Why / why not?
- Explain Bacon's method of induction. Do you think it is able to realize the aims of science? Why / why not?
- Explain two ways of saving induction. Do you think there work? Why / why not?