PH123 Elements of Scientific Method
Lecture 1
Introduction

What is Philosophy of Science?

"The aim of philosophy is to understand how things in the broadest possible sense of the term hang together in the broadest possible sense of the term." -- Wilfrid Sellars

One way of applying this idea to philosophy of science:

- What role does what scientists do (scientific research) and what they talk about (scientific entities) play within our overall understanding of reality and our place in it?

Some (epistemological) questions about what scientists do:

- What is the distinctive 'method' of science (if there is such a thing)?
- Why pursue the scientific method? (What are its goals, and are they good ones?)
- Do we have reasons for believing that the method of science is appropriate to its goals?

Some (metaphysical) questions about what scientists talk about:

- What makes something a 'scientific entity'?
- What is the relationship between scientific entities and our commonsense view of the world?
- Do we have good reasons for believing in scientific entities?

Science - Some contested areas

- Social Studies / Social Sciences faculty name change in 2009
- MMR
- Global warming
- "creation science"/"intelligent design"

The Philosophy of Science - three key guiding themes:

- The epistemology and metaphysics of science (and the relationship between them)
- Science and commonsense (continuities and discontinuities)
- Scientific rationality (rationality is not just logic, social structure of science)

A further issue:

- Science and Philosophy: naturalism - can science answer philosophical questions?

The problematic status of empiricism

Empiricism: The source of real knowledge about the world is experience. Science is successful because of its systematic treatment of experience

Troubles with empiricism (I): Experience – indispensable, yet unreliable

Example: Maskelyne & Kinnebrook (1796) – sometimes described as the birth of experimental psychology

- Nevil Maskelyne, the Astronomer Royal, dismisses his assistant David Kinnebrook.

- The issue: Kinnebrook's judgements of 'stellar transits' differed from those made by Maskelyne by 800 milliseconds. Maskelyne: Kinnebrook has fallen into "a vitious way of observing the times of the transists too late".
- Judging stellar transits: recording when a particular star passed the meridian wire in the Greenwich telescope – the running of the Greenwich clock depended on such transit judgements.
- Method used: the 'eye and ear method' – listening to the ticks of a clock while looking through the telescope, and then recording which tick coincided with the star crossing the wire.

What explains the 800ms discrepancy between Maskelyne & Kinnebrook? Two factors:

- Temporal order/simultaneity judgements between visual and auditory stimuli are affected by which modality is being attended to (*crossmodal prior entry*).
- People do not use the digits 0-9 equally when taking readings from a dial or scale. Maskelyne had a bias for recording readings that ended with a 2 or 3, Kinnebrook for those that ended with a 0.

▸ The reliability of experience is itself in issue that falls within the remit of scientific study. This results in a form of *holism*. The reliability of experience is not something science can take for granted, but something it must itself provide a vindication of as it progresses.

Troubles with empiricism (II): The Paradox of Empiricism

Example: The 'scientific revolution' – often considered to be the birth of modern science in general, and physics in particular.

- *Geocentric world view:* assumed a fixed earth, with spheres of planets and stars around it
- *Heliocentric world view*: Copernicus (*1473) correctly claimed that the earth rotates around its axis, and that the planets (including the earth) move around the sun

Two readings of Copernicus' theory:

- Osiander published Copernicus' work with a preface saying that the theory was not about reality, but merely a calculation tool.
- Galileo, by contrast, defended the theory as a theory about reality (for which he was put under house arrest)

The contrast between Osiander and Galileo may simply show different attitudes towards the (religious) authorities, who held on to geocentrism as a central part of religious doctrine and natural philosophy.

But it might also be taken to indicate something else:

- Even though the new theory is arrived at by 'empirical means', in some sense, the world it presents us with is, in certain respects, more removed from our direct experience.
- This tendency has become more and more prominent. The world described by science has become 'stranger' as science has progressed (consider black holes, quarks, Higgs bosons, etc.)
- If the 'goodness' of a theory ultimately depends on how well it handles our observations, what attitude should we take to the elements of the theory that don't correspond to the way we observe the world as being? (realism vs. anti-realism)

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Lecture 2
The 'Problem of Induction'

Induction and Deduction

Deductive arguments: Arguments that have *deductive validity* are arguments that transmit truth with certainty - if the premises are true, the conclusions must be true. For instance:

All humans are mortal	All pigs can fly
Socrates is human	Marvin is a pig
Socrates is mortal	Marvin can fly

Note: *Validity* is a property deductive arguments have in virtue of their *form*, whether the premises are true or not. An argument is *sound* if it is valid and the premises are in fact true. I.e., the argument on the left is sound, the argument on the right valid, but not sound.

Inductive arguments: An inductive argument takes as premises statements about individuals (typically expressing observations) and has a generalization as its conclusion.

Swan 1 is white,		
Swan 2 is white		
…	alternatively:	All observed swans have been white
Swan n is white		All swans are white
All swans are white		

Note: This argument does not have deductive validity. Even if all the premises are true, the conclusion may be false.

Two questions: (1) Does science in fact proceed by using inductive inferences?
(2) Can using inductive inferences yield knowledge?

Hume and the Problem of Induction

- If a proposition concerns a *relation of ideas* (e.g., bachelors are unmarried), its negation will imply a contradiction
- By contrast, there is no contradiction involved in supposing that a proposition that concerns a *matter of fact* (e.g., Pigs can't fly) is false, even if it is in fact true.
- We can learn about matters of fact only through the senses; not through deductive proof

The justification of induction and the uniformity of nature

- How can we justify an inference from a number of observations of non-flying pigs to the generalization that pigs can't fly?
- The inference can be justified if the belief in the uniformity of nature can be justified.
- Problem: The only possible grounds we can have for belief in the uniformity of nature are inductive, viz. that what we have seen so far of nature has been uniform.

Hume's conclusions:

(a) We reason in accordance with the rules of inductive inference, not because of a more fundamental belief in the uniformity of nature, but because it is in the nature of human psychology to do so.

(b) Yet, on a metaphysical level, there is no objective justification of induction. (And there are, of course, examples where the use of induction has led people to false conclusions: e.g. that all swans are white)

Responses to the Problem of Induction

(see also Ladyman: *Understanding Philosophy of Science,* and Stanford Encyclopedia article on induction)

(A) Attempts to make induction more similar to deduction (more on this next week)

(1) Induction can be justified through a further premise (a 'principle of induction'), in effect turning it into a deductive argument

If many X have been observed to be Y under many conditions, and no X has been observed that was not Y, then we are entitled to infer that all X are Y.
Many non-flying pigs have been observed, under many conditions, and no flying pig has been observed.
Pigs can't fly

Problem: How 'many' is enough? And, if we set a number, we arrive at the implausible conclusion that observations beyond that number have no bearing on whether we should believe the conclusion.

(2) Inductive arguments may not make their conclusion certain, but they make it more probable.

(3) Deduction can't be justified in a non-circular way either. We can give an inductive justification of induction (it has worked in the past, so can be expected to work in the future), just as we can give a deductive justification of deduction.

(B) Responses questioning the epistemology behind Hume's argument

(4) Induction is rational, even though we don't know how to justify it

We are more certain of the general rationality of induction than we are of the validity of Hume's arguments against it (compare Moore's response to skepticism about the external world).

(5) Externalism: *If* reality is uniform, induction is a reliable method.

(C) Responses questioning the applicability of Hume's argument

(6) Hume's argument does not capture the way we use induction

We in fact use 'principles of induction' of many sorts, don't always need many observations to generalize, or don't generalize even after many observations. Humans' use of inductive inference is much more sophisticated than Hume supposes.

(7) Hume only considers enumerative induction, but there are other forms of non-deductive forms of confirmation that are more promising, for instance "inference to the best explanation"

(8) Science does not use induction (Popper, see next week)

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Lecture 3
Induction and Confirmation

The ravens problem

Suppose you want to know whether H is true:

H: "All ravens are black"

- Intuitively, the way to confirm H is by finding as many ravens as you can, checking that all of the ones you can find are black, and that you can't find any white ones.
- Yet, H is logically equivalent to H* (i.e., it is impossible for H to be true but H* false, and vice versa)

H*: "All nonblack things are not ravens"

- Observation of a white shoe confirms H*, but if H* is logically equivalent to H, then it should also confirm H. This has struck many as paradoxical.

Responses to the ravens problem

(A) <u>Observation of a white shoe does confirm H</u> (though perhaps only by a tiny amount)

Rationale: Strictly speaking, H should be read as a statement about everything in the universe, i.e.

H': "Everything is either a black raven or not a raven."

Hempel: "In the seemingly paradoxical cases of confirmation, we are often not actually judging the relation of the given evidence, E alone to the hypothesis H ... instead we tacitly introduce a comparison of H with a body of evidence which consists of E in conjunction with .., additional … information which we happen to have at our disposal"

H: "All ravens are black" + I: "Things that can be nonblack include shoes"

If I already have the information that there exist white non-raven objects in the form of shoes, observation of a white shoe won't add anything to the stock of information I have.

Problem: This gives us a very idealized understanding of the relationship between a hypothesis and an observation. In actual cases, when scientists test a hypothesis, they do not set aside any prior information about the universe they may already have.

(B) <u>Whether or not observation of a white shoe (or indeed of a black raven) confirms H depends on the *procedure* you are using</u>

Consider a scenario in which you want to collect evidence for or against H. You meet four different people, each of whom hides an object behind their back. This is what they tell you:

S1: "I have a black object behind my back, want to see what it is?"
S2: "I have a raven behind my back, want to see what colour it is?
S3: "I have a white object behind my back, want to see what it is?"
S4: "I have a shoe behind my back, do you want to see what colour it is?"

- Hempel's point that the informativeness of an observation can depend on prior information already at your disposal is here made explicit in the first sentence used by each speaker.
- Rather than saying that we must therefore abstract from any such prior information, though, we might also say that whether an observation is evidence for a particular hypothesis depends on *what procedure it was part of*. In case S1, even an observation of a black raven adds no further support to H.

"Hempel was wrong to think that generalizations are always confirmed by observations of their instances. There is only confirmation (or support) if the underlying procedure was of the right kind." (Godfrey-Smith, *Theory and Reality*, p. 216).

Goodman's "New Riddle of Induction"

"grue" [def.]: A grue object is one that was first observed before August 2015 and is green, or was not observed before August 2015 and is blue.

Consider the following two inductive arguments, one using the familiar predicate "green", the other using "grue"

Emerald 1 is green	Emerald 1 is grue
Emerald 2 is green	Emerald 2 is grue
…	…
Emerald n is green	Emerald n is grue
All emeralds are green	All emeralds are grue

Goodman's argument:

- We suppose that the conclusion of the argument on the left is true, whereas that of the argument on the right is false (emeralds observed only after Aug 2015 will still be green).
- Yet, the arguments have exactly the same form.
- Thus, whether or not an inductive argument is a good one depends on the language we use.
- This contrasts with deductive arguments, which have validity purely in virtue of their form.
- There can't be a formal theory of induction.

A response:

- Intuitively, there seems to be something odd about the predicate "grue", in particular about the way in which dated observations ("observed before Aug 2015") figure in its definition.
- Not clear how this affects Goodman's argument. (Note that a deductive argument using "grue" would be equally valid as one using "green".)
- In particular, for someone growing up using the predicate "grue" and similar other colour-predicates (e.g. "bleen"), it would be *our* colour-predicates that would be odd in just this way.
- This does not mean, though, that "green" and "grue" must in fact be equally good predicates, though there is considerable controversy over what exactly might be wrong with "grue".

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Lecture 4
Karl Popper's Philosophy of Science

Three central themes in Popper's philosophy of science:

The demarcation problem: A central task of the philosophy of science is to explain the difference between science and pseudo-science

Inductive skepticism: Observations (even a large number of them) can never confirm a scientific theory

The idea of falsifiability: Observations (and sometimes just a single one of them) can, however, conclusively show that a scientific theory is wrong.

Popper on Science and Induction

Recap on induction: Inductive arguments do not have deductive validity: It is always possible for all the premises of an inductive argument to be true, and yet the conclusion to be false.

- One common reaction: Try to argue that induction is justified (in some way) even though it is not deductively valid (fallibilism).
- Popper's reaction: Induction cannot be justified (not even fallibly). What is false is the common assumption that science relies on induction. Instead, science relies on the *deductive* methodology of conjecture and refutation.

Falsification: the basic idea

There is a logical asymmetry between confirmation and falsification of a universal generalization (e.g. 'All swans are white')

- No matter how many positive instances of a universal generalization (e.g., individual white swans) are observed, it is always possible that the next observation will falsify it.
- One observation of the right kind (e.g., of a black swan) is enough to falsify a universal generalization.

The method of conjecture and refutation.

Step 1 - Conjecture: Scientist proposes theory from which observational predictions can be deduced, and which hence falsifiable.

Step 2 – Refutation: Scientist tests the observational prediction that can be deduced from the theory.

- If observations contradict the theory, the theory is rejected. Return to step 1.
- If observations do not contract the theory, continue holding the theory (for now), whilst generating further observational predictions that can be tested.

Normative claim: Science should be conducted through the process of conjecture and refutation.

Descriptive claim: Science actually proceeds through a process of conjecture and refutation

Falsifiability as the criterion of demarcation between science and pseudo-science

- Popper: For a theory to be scientific it has to take *risks* – that is, make predictions that can be falsified. Theories that fail to take risks are pseudo-scientific.
- Perhaps somewhat paradoxically, this means that a theory is more scientific, the less probable it is. A theory is more falsifiable (and hence less probable) if it makes precise predictions about a large range of phenomena. (*Bold* theories are better.)
- Theories with low probability have high informative content (they have the potential to tell us a lot about the world), whereas theories that are very probable anyway have low informative content.

Various ways in which to make a theory unfalsifiable

Vagueness:
- Sometimes invoked against 'intelligent design' claim that the complexity of life on earth shows that it was created by an intelligent being.
- 'Complexity' not a clearly defined notion. Any demonstration that one complex phenomenon can be explained without invoking God can be countered by saying that there are many other complex phenomena that are left unexplained.

Unfalsifiable prophecies.
- E.g., in horoscopes: "Events involving a stranger will put considerable strain on your love life unless you put your partner first."
- If your relationship runs into problems, you obviously didn't invest enough efforts in it.
- If it doesn't run into problems, it must be because you did invest enough efforts in it.

Ad hoc restrictions:
- Popper's example of Marxism might serve as an example here.
- Newspaper articles that seem to contradict Marxist interpretation of history can be discounted because they just show the class bias of the newspaper.

Science and Creativity

- *Conjecture* is a *creative process*. There is no recipe or logic for coming up with new theories, and how a theory has been arrived at plays no role in whether it is a good theory or not. (context of discovery)
- Philosophy of science is really only concerned with *refutation* (or the 'context of justification'). Whether a theory is a good one or not turns only on the way in which it is tested.
- Compare with Darwin's account of biological evolution in terms of random mutation and natural selection.

Two images of the scientist:

- Popper's theory describes scientists as boldly creative (conjectures) at the same time as being hard-headed in their willingness to give up theories that don't stand up to the severest possible tests (refutation).
- Compare this with Popper's picture of adherents of pseudo-science, who are so much in the grip of a theory that they can see only confirmations of it.

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Lecture 5

Problems with Popper

Problems with Popper's inductive scepticism

The plausibility of inductive scepticism

- For Popper, if a theory remains unfalsified (for the moment) after one of its predictions is tested, this does not add anything positive to the epistemic standing of the theory – we cannot conclude that it is true, probably true, or even just more likely to be true than before the test.
- Many have thought this counter-intuitive, and have thought that a theory's surviving a test should increase our confidence in it (but of course that would involve an element of induction, which is unjustifiable for Popper).

An example: Suppose there is a group of engineers that have to build a bridge, and who face the choice between two quite different theories:

(1) A theory that has been tested many times and has passed every test so far.
(2) A brand new theory that has just been conjectured and has never been tested.

We would ordinarily think that the rational thing to do is choose (1), but Popper's theory can't justify this choice.

A paradoxical element in Popper's position

- At the heart of Popper's philosophy of science is the demarcation problem.
- On the face of it, the question of what distinguishes science from pseudo-science is not just of psychological or sociological interest. The distinction has a *normative* dimension (i.e. science is *better* than pseudo-science in some respect).
- Yet, given Popper's inductive skepticism, it is not obvious how he can conceive of the distinction in normative terms. He is quite explicit that pseudo-science might come up with theories that are in fact true, and that the survival, to date, of a scientific theory provides no evidence that it is likely to be true.

A related problem: demarcation and theory-choice

Connected with the paradox just noted, Popper's falsificationism doesn't seem to provide us with any useful guidance as to which theories we should abandon, and which pursue further.

- In hindsight, it can seem easy to sort out science from pseudo-science in the manner envisaged by Popper, i.e. identify the theories that were abandoned because they could not be put to empirical test.
- Yet, our understanding of what might falsify a given theory can itself develop as part of the development of the theory. Thus, something that might look like a pseudo-scientific theory today may develop into a scientific theory

An example: Evolutionary theory

- Popper himself occasionally regarded Darwinism with some suspicion. One key worry has been that the basic idea of 'survival of the fittest' is circular in a way that makes it immune to falsification.

- But of course evolutionary theory has now developed into a complex package of ideas involving mathematical models, claims about the actual history of life on earth, as well as molecular biology, each of which is testable.

Testing Holism

"[A]n experiment in physics can never condemn an isolated hypothesis but only a whole theoretical group" (Duhem: Physical Theory and Experiment. In Curd & Cover: *Philosophy of Science*).

- A single observation only falsifies a (lengthy) conjunction of predictions and background assumptions.
- Whether or not an observation should count as falsifying a theory therefore requires making a decision: does the observation show that the theory itself is false, or only one of our assumptions as to how the theory might relate to data?
- What if someone were to argue that no sharp line can be drawn between the theory itself and assumptions about how it might relate to data (see Quine, week 5)? Then Popper's distinction between an *ad hoc* change to an old theory and an altogether new theory collapses. (Reminder: A change to a theory is *ad hoc* if it merely accommodates a specific observation without adding any other empirical content.)

Some other problems: Unfalsifiable elements in scientific theories

<u>Probabilistic theories</u>

- Many scientific theories make claims about probabilities. E.g. meteorology, climatology, certain theories in the social sciences, …
- It seems that a probabilistic theory cannot be falsified, so they are strictly speaking not scientific on Popper's view.

<u>Existential Statements</u>

- Scientific theories often make claims about entities or events that are potentially or in principle unobservable (atoms, quarks, dark matter, superstrings…)
- Existence claims cannot be falsified by failures to find such objects or observe such events (actually, that applies even to existence claims about ordinary objects)
- Popper bit the bullet on this issue and maintained that existence claims are not scientific theories, but they can be important meta-theoretical, metaphysical statements (which can provide inspiration for new scientific theories)

<u>Unfalsifiable scientific principles</u>

- There are some scientific principles that are taken by scientists as virtually unfalsifiable, e.g. the principle of the conversation of energy, the principle that there is "no action at a distance" (all physical causation is local), etc.
- Some important methodological principles: Theories should be unifying, theories should not be more complex than necessary (Occam's razor)
- Normally, these are counted towards the stock of scientific logic. Popper could again deal with them, though, by counting them as metaphysical principles

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Lecture 6
Thomas Kuhn

Where we are

The problem of induction – two types of responses

- Try to beef up inductive inference in some way to respond to skepticism about induction (logical empiricists)
- Embrace inductive skepticism, but argue that science does not rely on induction (Popper)

Common elements of approaches to science prior to Kuhn:
(see Ladyman: Understanding Philosophy of Science, ch. 4)

- Science is cumulative (empiricists), or there is at least some sense in which the history of science can be said to involve a 'progression'
- There can be something like a general description of the fundamental methods of science that applies to all branches of science, some of which can be given a formal description (logic of confirmation or falsification)
- There is an epistemologically crucial distinction between the context of discovery and the context of justification
- There is a sharp distinction between observational and theoretical terms, and theoretical terms have fixed and precise meanings
- The history of science can be reconstructed as a series of rational decisions

Key elements in Kuhn's theory I: paradigms and the idea of 'normal science

Paradigm: Not very clearly defined by Kuhn (one critic claimed that Kuhn was using the word in 21 different senses), but two key ideas are the following

- A paradigm as a type of *framework*: a package of claims about the world, methods for collecting and analyzing data, habits of scientific thought and action – i.e. a *way* of doing science in a particular field.
- A paradigm as an *exemplar* (compare: the robin is a paradigmatic bird, the penguin isn't): scientific research is guided by the example of particular famous experiments, influential attempts to capture phenomena through a set of laws, or formalizations that are being seen as particularly effective in conveying information.

Normal science: Kuhn uses the term 'normal science' for periods of time in which one particular paradigm guides (a group of) scientists' work. During normal science, scientists' work is 'puzzle solving':

- They do not abandon the paradigm if they encounter some anomalies
- Rather, they try to accommodate the anomalies within the paradigm

Key elements in Kuhn's theory II: Crisis and revolution

Crisis: When normal science encounters too many anomalies, the paradigm is in *crisis*. The anomalies start to be seen as indications of a deeper problem.

Revolution: When a new paradigm emerges in crisis, a *scientific revolution* takes place.

- A new, alternative, paradigm has to be available before scientists give up an old one.
- The new paradigm, just like the old one, may face serious anomalies
- The move from the old to the new paradigm is not a rational choice, because there is no common standard according to which they can be compared with one another.

Kuhn vs. Popper:

Kuhn: Both normal science and scientific revolutions are central to the historical development of science, but neither fits Popper's account of science.

(1) Normal science
In periods of normal science, scientists are right to try to accommodate anomalies within their existing paradigm, rather than rejecting the paradigm.

The argument from testing holism:

- Because of the problem of testing holism, it can sometimes be beneficial to hold on to a given theory in light of apparent disconfirmation.
- The apparent disconfirmation might point, not to a problem with the theory, but to a problem with another assumption we are making (of which we may hitherto not even have been fully aware).

Example: The discovery of Neptune

- The orbit of Uranus contradicted predictions derived from Newton's mechanics
- Scientists held on to Newton's theory, and subsequently discovered Neptune, which explains the observations

The argument from the sociology of science

- Giving up scientific theories too quickly due to anomalies would prevent scientific success
- Sustained scientific inquiry is a social achievement, which requires cooperation and consensus between scientists
- Cooperation and consensus can only emerge if debates about fundamentals are closed off during periods of normal science (think also about investments in equipment, political decisions about funding, etc.)

(II) Revolutions
The paradigm-shift that occurs in revolutions cannot be described as move from one falsifiable, and falsified, theory, to another falsifiable, but not yet falsified, theory.

- Kuhn: Paradigm choice "cannot be made logically or even probabilistically compelling for those who refuse to step into the circle" (The Structure of Scientific Revolutions, p. 94)
- Compare here Popper's description of those in the grip of a pseudo-theory: "The study of [e.g., Marx or Freud] seemed to have the effect of an intellectual conversion or revelation, opening your eyes to a new truth hidden from those not yet initiated." (Conjectures and Refutations, p. 35)

[Note though one element in common between Kuhn and Popper: Neither gives us a reason for thinking of progress in science as bringing us closer to the truth.]

PH123 Elements of Scientific Method
Lecture 7
Kuhn on Scientific Revolutions and Incommensurability

Paradigms and Revolutions

"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)

- Which paradigm scientists work in cannot be exhaustively explained by the observations they have made
- There is always an arbitrary, non-rational ingredient involved in paradigm-choice
- Connectedly, there are no 'rules' governing the move from one paradigm to another.
- Such moves are disorderly events, i.e. revolutions.
- The orderly assessment of ideas breaks down, and even the most basic ideas are put back on the table

A (limited) analogy: Gestalt switches

- Gestalt switches are not completely under voluntary, rational control; to some extent, they 'just happen'
- You can't see the picture in both ways at the same time
- [A potential further analogy, related to Kuhn's claims about reference incommensurability (see below): Each way of seeing the picture involves seeing a different set of objects]

Incommensurability of standards

"To the extent […] that two scientific schools disagree about what is a problem and what a solution, they will inevitably talk through each other when debating the relative merits of their respective paradigms." (*The Structure of Scientific Revolutions*, p. 109)

- Standards of assessing the relative merits of a theory can themselves differ across different paradigms.
- This introduces one type of relativism into Kuhn's theory: It is [sometimes] only relative to the particular paradigm that we are working in that one theory can be called superior to another.
- Kuhn later maintained, though, that this relativism is compatible with there being some general normative principles about science:

  Theories should be predictively accurate
  Theories should be consistent with well established theories in neighbouring fields
  They should unify disparate phenomena
  They should be fruitful to new ideas and discoveries

  Because these normative principles apply to science in general, Kuhn falls short of claiming that science is completely irrational
  Yet, the above values are not sufficient to determine decisions, as they may conflict. Thus a non-rational (rather than irrational) element remains

Incommensurability of language

A case Study: Lavoisier and the 'Chemical Revolution'

Phlogiston theory:

- Materials have three basic parts: phlogiston, impurities, and the pure material itself
- Phlogiston is released when things burn
- Some substances burn better than others because they contain more phlogiston
- Fires stop to burn in closed containers because the air gets saturated with phlogiston

The crisis of phlogiston theory:

- Phlogiston theory started to run into trouble when it was observed that some metals (such as magnesium) gained weight when burned
- Intense discussion about the weight of phlogiston
- Response: proliferation of different methods and phlogiston theories to deal with the problem (Kuhn interprets such proliferation of theories as a general sign of crisis)

Lavoisier and the 'chemical revolution':

- Systematic use of quantitative methods: Use of closed vessels shows that combustion requires a gas that has weight (oxygen)
- Oxygen plays a very different role in combustion from that envisaged for phlogiston
- Oxidation: burning not explained as release of an element, but in terms of the idea of oxygen reacting with other substances.

Meaning incommensurability

- Kuhn holds that scientific terms get their meaning from their position within the overall theory.
- E.g., oxygen, as conceived of by Lavoisier, is not just an element of the types envisaged by phlogiston theory
- Thus, scientific terms that figure in one theory cannot be translated into terms that figure in a rival theory (especially if the theories belong to different paradigms)

Reference incommensurability

- Kuhn also sometimes makes (arguably) stronger claims such as that "when paradigms change, the world changes with them"
- E.g., the different theories about burning invoking phlogiston and oxygen, respectively, are really theories about two different things, and thus we have no reason to believe that science has made any progress understanding the underlying nature of things.
- Thus understood, Kuhn has sometimes been interpreted as putting forward a variety of anti-realism about science, according to which scientific entities are socially constructed.

The lasting legacy of Kuhn

- Kuhn is often criticized for overstating his incommensurability claims.
- It is also not always clear where he stands on the idea of progress in science.
- Perhaps his most important legacy is the idea of science as a social enterprise, depending on specific forms of social and institutional frameworks

PH123 Elements of Scientific Method
Lecture 8
Scientific Realism and Anti-Realism

Varieties of realism and anti-realism:

Common sense realism:

- A claim about common-sense objects (tables, chairs, etc., as we ordinarily think of them).
- The claim is that such objects (and at least some of their properties) have an objective existence independently of us and of how we experience or think about them.

Anti-realism about particular properties of common-sense objects:

- Distinction between *primary qualities* (actually possessed by the object) and *secondary qualities* (somehow dependent on our point of view on the object)
- Examples of such 'secondary qualities' may include: monetary value, aesthetic properties (beautiful, ugly), funniness, colour

Scientific anti-realism:

- Typically held in connection with common-sense realism about tables, etc.
- The claim is that the unobservables postulated by science (electrons, quarks, etc.) do not literally exist; they are in some sense just theoretical constructions.

Strong scientific realism:

- Rejection of both common-sense realism about objects, and scientific anti-realism
- The only entities that, strictly speaking, exist independently of our experience are those postulated by science; it is our common sense picture of the world that is a construction

Arguments for strong scientific realism

- The viability of common sense realism seems to turn on the possibility of drawing a clear distinction between primary and secondary qualities as qualities of common sense objects. Yet, "the only candidates for primary properties that physical science now ascribes to things [e.g., charge, isospin, etc.] lack any counterparts in our experience." (Ladyman, *Understanding Philosophy of Science*, p. 144)
- "[Science] is the strategy of subjecting even the biggest theoretical ideas, questions and disputes to testing by means of observation. This strategy is not dictated to us by the nature of human language, the fundamental rules of thought, or our biology" (Godfrey-Smith: Theory and Realty, p. 223f.)

A problem for strong scientific realism: "If we say that scientific reasoning does assume common-sense reasoning, we seem to be committed to holding on to an everyday, unreflective picture of the world, regardless of what science ends up saying. But if we sever scientific realism from common-sense realism, it becomes hard to formulate a general claim about how the aim of science is to describe the real world." (Godfrey-Smith: *Theory & Reality*, p. 175)

Scientific anti-realism I: Instrumentalism

Key claim: Statements about unobservables in science should not be read literally, i.e. as postulating a certain kind of existent. Rather, they are shorthand for instructions as to how to make predictions.

- Perhaps a good way to approach some statements in the social sciences (e.g. about "supply" and "demand", or the "average tax payer").
- Such statements are ultimately reducible to other statements, but allow for less complex, more abstract or idealized way of capturing facts under investigation.

Scientific anti-realism II: Van Fraassen's constructive empiricism

Van Fraassen: "Science aims to give us theories which are empirically adequate; an acceptance of a theory involves a belief only that it is empirically adequate."

"aims": Van Fraassen thinks that realism/anti-realism debate is about understanding the kind of theory science aims for. The fact that an existing theory can go wrong in the kinds of entities it postulates does not decide the debate.

"empirically adequate": different from 'true'. Empirical adequacy means only that it makes correct predictions about directly observed phenomena ('saving the phenomena')

"acceptance": Van Fraassen thinks that scientific statements about observables are capable of being literally true (in contrast to instrumentalism). His point is that the rational attitude that should drive us to accept/reject them is simply the belief in their empirical adequacy (compare agnosticism in religion)

Arguing against scientific anti-realism – inference to the best explanation

A common form of scientific reasoning is *inference to the best explanation*. If a theory provides the best explanation for a particular set of phenomena, this is usually taken as evidence that the theory is *true* (and not just empirically adequate).

<u>The local defense of scientific realism</u>

- Thinking of the observable behaviour of substances like water, iron, etc. as determined by an underlying molecular structure can explain a vast range of phenomena.
- Therefore, molecular theory is a better explanation than rival theories that can only explain some of these phenomena.
- Thus, we should infer that the unobservables postulated by molecular theories exist.

<u>The global defense of scientific realism:</u> "The positive argument for realism is that it is the only philosophy that doesn't make the success of science a miracle" (Putnam).

- Science as a whole is extremely successful in predicting new and surprising phenomena
- It does so by postulating unobservables
- Therefore, we should infer that those unobservables exist

<u>Three responses:</u>

- In everyday life, we use inference to the best explanation to infer the presence of unobserved, but in principle observable entities (i.e. we have independent grounds that such entities exist). In the case of science, using inference to the best explanation would require us to believe in an entirely new type of entity.
- Inference to the best explanation is not compelling even in the case of the observable. There is nothing irrational about accepting the premises, but not the conclusion.
- The success of science can be explained on Darwinian grounds. Only theories that do successfully predict the phenomena survive in the long run.

PH123 Elements of Scientific Method
Lecture 9
The Problem of Underdetermination

Underdetermination: two already familiar ideas

(1) *The problem of induction*: the premises of an inductive argument underdetermine the conclusion in the sense that the former may all be true and yet the latter false.

(2) *Testing holism*: Scientists cannot test a single hypothesis or claim in isolation. Only whole theories (including assumptions used in the process of deriving predictions from them) can be put to empirical tests.

Quine's 'Two Dogmas of Empiricism'

The two dogmas:

(1) *The analytic/synthetic distinction*: There are statements (i.e. analytic ones), which are true or false only in virtue of the meanings of their constituent terms, i.e. independent of empirical facts.

(2) *Reductionism*: All synthetic statements (i.e. ones that do record empirical facts) can be reduced to observation statements.

Quine's holism:

Thought/language connects with experience not on the level of statements, but on that of the complete body of statements that make up a thinker's 'web of belief' as a whole.

From this perspective, the two dogmas stand and fall together (they are two sides of one coin):

- Reduction of synthetic statements to observation statements is not possible unless there are rules for carrying out the reduction that are not themselves sensitive to what we observe (i.e. analytic).
- Analytic/synthetic distinction can only be upheld if there is a principled way of separating out through reduction a 'linguistic component' and a 'factual component' of a given statement (i.e. a component that isn't, and a component that is, sensitive to what we observe).

"Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system. Even a statement very close to the periphery can be held true in the face of recalcitrant experience by pleading hallucination or by amending certain statements of the kind called logical laws" (Quine)

Ingredients in Quine's view

- *No two-process view of science* (contra Kuhn): There is no principled way of distinguishing between changes in science that happen within (and guided by) a framework, and changes that involve one framework being replaced by another.
- *Common sense continuous with science*: On Quine's view, *any* belief is in some sense theoretical, i.e. defined by its place within the overall web of beliefs. There is no in-principle difference in the way common-sense beliefs and scientific beliefs connect up with experience.

- *Naturalism*: There is no such thing as a priori reasoning or pure 'conceptual analysis'. Hence, there are no (meaningful) 'philosophical' questions on the answers to which the science might not have an impact (see Quine's 'Epistemology Naturalised').

Weak underdetermination vs. strong (Quinean) underdetermination

Weak underdetermination: All the data we have gathered to date are consistent with more than one theory

- May allow for further data to resolve which theory is the right one
- Even if it is always possible to come up with further theories that fit the same given data, these may not be equally good (compare Laudan on deductive vs. ampliative underdetermination)

Strong underdetermination: Any theory can be reconciled with any recalcitrant evidence by making suitable adjustments in our web of beliefs.

- Any reasons we might have for preferring to adjust our overall web of beliefs in one way rather than another to a piece of evidence is purely pragmatic.
- Not just empirical science, but also mathematics and logic are affected by underdetermination problem
- Gives us a recipe for generating *strongly empirically equivalent theories* – rival theories that have the same empirical consequences not just for what we have observed so far, but also for any possible future observations
- The idea of strongly equivalent empirical theories seems incompatible with realism.

Responses to strong underdetermination

(A) How plausible is the idea that mathematics or logic are open to empirical revision?

- There are actual examples where evidence for a physical theory has been taken to falsify a part of Mathematics (i.e. general relativity replaced Euclidian with Riemannian geometry)
- There may, however, be logical/mathematical rules that we are hard-wired to follow (i.e., as a matter of psychological fact, there may be a certain part of our web of belief that we cannot change). – Not clear how that would affect import of Quine's points, though

(B) Does Quine adequately account for rational principles of theory choice?

- Even if two theories are empirically equivalent, there may be rational grounds for preferring one to the other. Good theories…

  explain, rather than just entail, the evidence (contra, e.g., instrumentalism)
  have been tested against a diverse range of phenomena under different conditions
  unify diverse phenomena
  are ontologically parsimonious...

Van Fraassen: Even if there are such rational grounds for accepting one theory rather than another, these may not be grounds for accepting the theory to be *true* (rather than just empirically adequate). The problem for realism thus remains.