Week 11

Local reduction

Nagel, Feyerabend

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Outline

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1 Review and preview

Review of the last lecture: global reduction

- Last week the subject was reduction across disciplines.
- This approach involved an ontological assumption that the reducing theory has in its domain 'smaller' objects than the reduced theory.
- The approach was motivated by the search for the unity of science.
- It was allowed, however, that any such actual reduction may forever remain elusive.
- The objection was made in terms of a contrastive explanation.
- If an explanation answers the question 'Why this and not that?', then the answers will be different at different reductive levels.

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Preview of this lecture: local reduction

- This week our subject is a related, but still different, kind of reduction.
- This other reduction is *intra*disciplinary and *inter*theoretic.
- It does not make assumptions about ontology.
- However, just like with Oppenheim and Putnam, 'to reduce is to explain.'
- We are not looking for a unity of science.
- Rather, we look for the continuity within the same discipline.
- We want to understand the relationship between successive theories of the same discipline.
- In short: global reduction tries to make sense of the current state of science, local reduction tries to make sense of the history of a particular discipline.

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2 Structure of theories

Experimental laws and theories

- Our selection begins abruptly with the distinction between experimental theories and laws, so a few words are in order on what it is about. (Though the material may be familiar by now.)
- Consider the law that water boils at 100°C, or the law that every body in a free fall has the same acceleration, or indeed Boyle's law.
- These laws are distinguished, first, by their specificity, and second, by their proximity to observation.
- The terms of these laws have their meanings fixed through a certain laboratory procedure.
- By contrast, the more abstract and general *theories* (such as kinetic theory of gas, atomic theory of molecules, Newtonian mechanics) will be remote from observation.
- They will also be used to explain experimental laws.
- Also, we may think of experimental laws as inductive generalisations.
- But, while theories may be *supported* by evidence, they cannot be directly generalised from the available evidence.

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Theories as calculi

- We think of scientific theories as axiomatic theories that have empirical content.
- Therefore, we first identify the purely formal calculus.
- This calculus will be characterised by logical terms, non-logical terms, and rules of inference.
- Non-logical terms: 'molecule', 'atom', 'electric charge'.
- They will not be explicitly defined by the theory.
- Instead, their relational properties will be specified.
- Thus these terms will be *implicitly* defined.

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Rules of correspondence and models

- Calculi should be equipped with rules of correspondence.
- Their role is in connecting calculus terms with observation.
- That is: non-logical terms contained in the calculus will be empirically *interpreted* by these rules.
- In addition, theories require models.
- Their role, however, seems to be merely heuristic (as in Bohr's theory of atom as a miniscule Solar system).

Question
Critically compare Reichenbach's notion of coordinative definitions and Nagel's notion of correspondence rules.

Question
Should the laws/theories distinction contradict Bridgman's operationalism?

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Some implications of Nagel's view

- Not every theoretical term can be put in correlation with observation.
- Theories are 'partially interpreted' formal calculi.
- There is a (relatively) clean separation between theoretical apparatus and observation data.
- Since theories are axiomatised formal systems, it is to be expected that, if any interesting relation exists between two distinct theories, it will be some form of logical entailment.

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3 The Common View

The Common View: continuity between theories

- New theories extend the range of application of earlier theories.
- That is, old theories are special cases of the new theories.

Example 1 (Newton/Einstein). Newtonian mechanics holds for low relative velocities. It was a mistake to apply it to high velocities.

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The Common View in a physics textbook

> Subatomic particles behave in a more complex way than the material points of the classical mechanics. The classical picture only approximately reflects the laws of nature.
>
> Newton's theory of gravitation was further developed in Einstein's general theory of relativity. This latter gives not an intuitive explanation of gravitation, but a new way of describing it and a generalisation of Newton's theory.
>
> The theory of relativity and quantum mechanics are more general theories than Newtonian mechanics. The latter is contained in them as an approximate limiting instance. Relativistic mechanics merges into Newtonian mechanics in the case of low velocities. Quantum mechanics merges into Newtonian mechanics in the case of sufficiently massive bodies moving in smoothly varying fields.

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Approximation?

$$
\begin{aligned}
x' &= \frac{x - ut}{\sqrt{1 - \frac{u^2}{c^2}}} \\
y' &= y \\
z' &= z \\
t' &= \frac{t - \frac{ux}{c^2}}{\sqrt{1 - \frac{u^2}{c^2}}}
\end{aligned}
$$

$$
\begin{aligned}
x' &= x - ut \\
y' &= y \\
z' &= z \\
t' &= t,
\end{aligned}
$$

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Positivist reduction

- On the Common View, a less general theory will hold in special cases that, however, can be ubiquitous.
- So we represent this claim thus:

  $$\text{If } (T \,\&\, d), \text{ then } T', \tag{1}$$

  where T is a more general theory T' is a less general one, and d is a statement describing the special case (compare page 144).
- If (1) holds, then we say that T' is reducible to T.
- Now for this entailment (1) to be valid, a further constraint must be satisfied.

Meaning constraint
The meanings of terms used in the derivation must be kept constant (the condition (4) in page 142).

Question
Why is there a need for the meaning constraint?

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Logical properties of the reduction If $(T \& d)$, then T''

- Generally speaking, the theory T deals with a range of phenomena wider than the range of T''.
- Hence the domain of T contains the domain of T'': $D' \subset D$.
- Nevertheless it is also clear that T'' must be consistent with T within its narrower domain D'.
- This demand of consistency is trivially satisfied if we make a stronger assumption (as the positivists apparently do) that T entails T''.
- This is the content of the condition (5) in page 143.

Question
How is consistency related to entailment?

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4 Galileo and Newton

The first example: Galileo and Newton If $(T \& d)$, then T''

- In Galilean mechanics the distance travelled by a falling body is computed by the formula:
$$s = g \times t^2.$$
- The assumption here is that the vertical acceleration is expressed by the constant g.
- However, this claim is incompatible with Newton's law of gravitation.
- The claim d will mention a minuscule variation in the distance between the falling body and the earth (that is, minuscule in comparison to the radius of the earth).
- But then the derivation will not go through: acceleration is to grow, as the body approaches the earth, according to Newton's law of gravitation.

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The failure of reduction

- Feyerabend diagnoses the problem with the empirical underdetermination of theories.
- The same piece of evidence can be compatible with very different theories.
- The two theories can be confirmed by that evidence to the same degree, yet rest on fundamentally different theoretical premisses.
- Those premisses will block any attempt of reduction.

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5 The problem of motion

Some facts of the neo-Aristotelian mechanics

- Generally, the idea of ascribing 'energy' to a moving body only by virtue of its motion cannot be accommodated in the Aristotelian physics.
- In an early influential treatise *Problems of Mechanics* 'power' is defined as a product of weight and velocity. This power, attributed to *agency*, sets the body in motion.
- Later commentators (Buridan) developed a theory of *impetus*.
- It is this impetus which moves a stone that has been thrown (a projectile).

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Buridan I

> Whenever some agency sets a body in motion, it imparts to it a certain *impetus*, a certain power which is able to move the body along in the direction imposed upon it at the outset, whether this be upwards, downwards, to the side or in a circle. The greater the velocity that the body is given by the motive agency, the more powerful will be the *impetus* which is given to it. It is this *impetus* which moves a stone after it has been thrown until the motion is at an end. But because of the resistance of the air and also because of the heaviness, which inclines the motion of the stone in a direction different from that in which the *impetus* is effective, this *impetus* continually decreases. Consequently the motion of the stone slows down without interruption. Finally the *impetus* is overcome and destroyed at the point where gravity dominates it, and henceforth the latter moves the stone towards its natural place.

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Buridan II

- An interesting consequence of this view is that the mysterious *impetus* stays in the body indefinitely, until and unless it is suppressed by the resistance of the medium (e.g., air) or by some agency.
- This is a strikingly modern view.
- It appears that, at least in the case of projectiles, impetus is the source of motion.
- This is further confirmed by Buridan's own words when he says that impetus explains acceleration:

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Buridan III

> The existence of impetus seems to be the cause by which the natural fall of bodies accelerates indefinitely. At the beginning of the fall, indeed, the body is moved by gravity alone. Therefore it falls more slowly. But before long this gravity imparts a certain impetus to the heavy body—an impetus which is effective in moving the body at the same time as gravity does. Therefore the motion becomes more rapid. But the more rapid it becomes, the more intense the impetus becomes. Therefore it can be seen that the motion will be accelerated continuously.

- As for the numerical value of impetus, Buridan says that it increases with velocity, on the one hand, and is proportional to the density and volume of the body, on the other.
- This is a reason to link it to the modern momentum.

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Leonardo

- It is also interesting to mention Leonardo's views on impetus.
- He distinguished three phases in the motion of a projectile.
- In the first phase, the motion is *violent* and is entirely under the influence of impetus.
- In the last phase it is *natural*, since it is under the influence of natural gravity.
- In the middle phase we have a mix.

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Galileo's principles I

Galileo introduced the concept of momentum ('momento') in his work on hydrostatics. In a curious passage combining the reference to both 'momento' and 'impeto', he writes:

> I borrow two principles from the Science of mechanics. The first is this—two absolutely equal weights that are moved with equal velocities are of the same power, or the same *momento*, in all their doings.
> To students of mechanics, *momento* means that property, that action, that efficient power by which the motive agency moves and the body resists. This property does not only depend on the simple gravity, but also on the velocity of motion, the different inclinations and the different distances travelled. Indeed, a heavy body produces a greater *impeto* when it descends on a very steep surface than when it descends on a surface which is less steep. Whatever may be the ultimate cause of this property, it always keeps the name *momento*.

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Galileo's principles II

> The second principle is that the power of the gravitation increases with the velocity of the thing that is moved, so that absolutely equal weights that are animated with unequal velocities have unequal powers, strengths, unequal momenti. The more rapid is the more powerful, and this in the ratio of its own velocity to the velocity of the other weight...

Notice the claim that momentum is the product of mass and velocity. Compare this to Buridan's views.

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Feyerabend's critique

- Feyerabend admits that the numerical value of momentum and impetus is calculated in the same way.
- That is, however, an insufficient ground for identifying one with the other.
- First, quite generally, momentum is not a result of motion, not its cause.
- Second, consider a body moving with constant velocity (i.e. set in uniform motion). It has momentum. But what would be its impetus (according to the neo-Aristotelians)?
- Well, this is hard to say. This motion will have to be originated from a 'push': it must necessarily be violent. That impetus will set it in motion.
- But according to the Newtonian mechanics, inertial motion is not in need of any push.
- It is a natural state of material bodies.

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Extension and intension

- Feyerabend argues that though the actual extensions of momentum and impetus may coincide, their intensions do not.
- Impetus, however calculated, is necessarily an attribute of forced (violent) motion.
- Momentum can accompany unforced motions.
- There are, I think, other problems as well.
- What are we to do with the Aristotelian power? It cannot be assimilated to force, at least for quantitative reasons.
- But it is designed to capture the same empirical phenomenon of 'pushing', setting in motion.
- And also, impetus was not clearly distinguished from power.
- Thus momentum cannot be impetus.

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6 Diagnosis

Diagnosis

- Certain 'principles of context', and 'rules of usage' are associated with a given theory (page 153).

- They are not inherited by its successor.
- What happens in scientific change is a replacement of the ontology of the defeated theory by the ontology of the victor (page 152).
- Therefore, the concepts employed by rival theories are ‘incommensurable’.
- In plain words, one cannot be explicated by another.
- The conclusion extends to natural languages.
- Those are not theoretically innocent: they were designed to give expression to ‘some theory or point of view’. 25

Homework 3

In what way(s) can the Darwinian argument qualify as a scientific revolution? 26