Causation

Lectures 5 & 6

Action at a distance

1. Hume's 'contiguity' requirement

Hume held that causes are 'contiguous' with their effects – i.e. that they adjoin them in space and time. Let's focus this week on space (time next week).

This requirement is often described as the 'locality' requirement; and causation which is not local is known as 'action at a distance'. So Hume's position is that there is no action at a distance – all causation is local.

It's worth noting that the thesis that there is a 'regular' connection between causes and effects does not imply that causes must be local. On the face of it, there could be a lawlike connection between events, properties (or whatever) which are separated by a significant 'distance'.

Equally: one can see the intuitive appeal of the locality requirement: we think of there being a causal 'chain' connecting causally separated events, and the suggestion that no such connecting chain seems, on the face of it, to invite the accusation that the causation is 'magical': suppose I wave my hand here in York, and down in London something happens which is said to be an effect, but without any connecting sequence of events. Not seriously credible, one would think.

2. Aristotle and Newton.

Aristotle distinguished between 'natural' and 'violent' motion. 'Violent' motion is motion which is the result of some interaction (e.g. I throw a stone); here the motion is clearly the result of a 'local' interaction. But 'natural' motion – e.g. a stone falling to the ground - is not, on the face of it, the effect of any local interaction. But equally this motion has no external cause: rather, it's of the 'essence' of material things to move that way. So there is no action at a distance here either.

Jumping now to Newton: he distinguishes between

(i) rectilinear inertia
(ii) interaction (action and reaction are equal and opposite)
(iii) acceleration as a result of gravitational attraction.

(i) Rectilinear inertia is comparable to Aristotelian 'natural motion' (though Newton denies that an object's falling downwards is a matter of inertia alone): precisely because no external force is applied, a body is carried along by its own inertia, as we say. So because there's no 'action', there's no action at a distance;
(ii) Interaction clearly is 'local' (though we'll see that there are some complexities here); so that's not action at a distance.

(iii) Gravity, however, is different: it's not a case of inertia and does not appear to be a matter of interaction. So it looks like action at a distance. Newton famously refrained from affirming this view and seems to have supported the view that some kind of 'corpuscular' action was involved. But he had no theory, no 'hypothesis'.

So gravity is a core issue for debates about action at a distance: e.g. the tides of the sea are explained as an effect of the moon's gravitational 'pull' – but the moon is c. 250,000 miles from the earth. Surely that's action 'at a distance'.

3. Locality

The intuitive thought about locality is that cause and effect come into contact – i.e. the cause 'touches' the effect, or something similar. But this assumes that space has nice sharp boundaries such that it makes sense to suppose that where the cause occupies one position, the effect occupies the 'next' position, so that there is no empty space between them – i.e. they are touching.

But space is not like that. Spatial lengths are not measured in 'whole' numbers (1, 2, 3, …..) where it makes good sense to speak of the 'next' number; instead spatial lengths are measured in 'fractions' (rational numbers, such as 3/6 or 7/12) or even 'real' numbers such as $\sqrt{2}$ (as in the diagonal of a 1 x 1 square). Numbers of this kind are 'dense' (or 'compact') in the sense that between any two rational numbers, there are infinitely many further rational numbers. So it makes no sense to talk of the 'next' number; and thus, equally, no sense to talk of 'contiguous' places.

Instead we have to accept that objects (and thus events) cannot quite 'touch'; but what we call touching is where the gap between them is arbitrarily small – i.e. we can always bring them closer than any distance between them, however small.

Does that undermine 'locality'? Not exactly – but it indicates that we have to think of causal, interactive, influence as transmitted through space; i.e. locality is action at an arbitrarily small distance.

In which case, perhaps we should not find action at a large distance so very mysterious.

4. Fields

Let's leave gravity to one side for the moment. What about sound? Is hearing someone speak a case of action at a distance?

Clearly not: spoken sounds are waves in the air, produced by vocal chords in one's voice box and registered via the hearer's ears (thanks to the cochlea located there). This then gives one a straightforward case of a 'field' – an auditory field of air waves.

What of other cases? e.g. magnetism and electromagnetism. Here again we speak readily of a field, with 'lines of force' that can be pictured by iron filings radiating around the poles of a magnet or a charged wire. But what's going on here? It became apparent that the phenomena here are wavelike – they give rise to wavelike phenomena such as diffraction patterns; and the frequency and amplitude of the waves can be investigated etc. But waves of what? Not air (unlike sound, electromagnetic radiation is transmitted through a vacuum). It wasn't clear – but the hypothesis was that there needed to something which 'carried' the waves – hence the hypothesis of the 'aether', an unknown 'aetherial' substance which was activated by magnets and electric currents etc.

On this model, electromagnetism is like sound, and does not involve action at a distance. Further: the model could be extended to apply to light: light was also known to be wavelike (it gives rise to diffraction phenomena etc.), and Maxwell famously showed that light is another part of the electromagnetic spectrum.

BUT, early in the 20th century the American scientists Michelson and Morley argued that if the aether exists, then the speed of light should vary depending on whether the earth was travelling in the same direction as the propagating waves of light, or in the opposite direction. They then constructed a simple, but very very sensitive instrument to measure these variations in the speed of light – and found that there were NONE. It appears that the speed of light is constant. That is strong evidence against the aether hypothesis.

5. Fields without aether.

One response to the MM result was to become anti-realist about fields: to hold that they have no intrinsic reality and are just ways of describing how objects placed in the proximity of magnets, electric currents, light emitters etc. are liable to behave. On an anti-realist position of this kind, all these phenomena involve action at a distance.

But that isn't very persuasive. After all, it turns out that one can bend electromagnetic fields, or spin them around etc. So it looks as though there is some 'substance' to them.

6. Quanta

The key to understanding them turns out to lie with the strange behaviour of the packages of energy we know as quanta, which come in various forms – electrons, protons, photons and others. Photons, in particular, are crucial to electromagnetic fields. They inherit the ancient thought that light involves the emission of very small corpuscles – except that photons aren't particles; instead they are 'clouds' of energy that form wavelike patterns, especially as they interact with objects.

Photons are, indeed, very weird; but we don't need to know much about them. All we need to accept is that electromagnetic radiation is basically the excitation or radiation of photons whose energy is transmitted in such a way as to give rise to the familiar attractive/repulsive/reflective results that we associate with magnets, light sources etc. Hence there is here a 'real' field, and no fundamental action at a distance.

7. Gravity

How, finally, should we think of gravity? Is gravity also a strange quantum field, somehow generated by masses. Some theorists seem to think so, and write of ‘gravitrons’ – as a distinct type of quanta to ‘carry’ gravity through space.

My own grasp of these matters is limited (!!) But my sense is that within Einstein’s General theory of relativity there is a programme of assimilating gravity to space (or rather space-time) itself, as if gravitational motion was a kind of inertial motion within a space which is ‘curved’ by masses which, for Newton, exert a gravitational attraction upon each other. It certainly counts towards this approach that one of the important features of General relativity is that it unifies the conceptions of inertial mass and gravitational mass, which are conceptually distinct but empirically equivalent in Newton’s theory. But there is a great deal of complexity here, concerning what counts as ‘inertial motion’ in the General theory.

But if this is even roughly right: then gravity is no more of a problem re locality than inertial motion in Newton or natural motion in Aristotle.