Philosophy of Science // Fall 2015

Handout 2
Mach's positivism

Etymology of 'mass'. One of the central claims Mach makes is the circularity in Newton's definition of mass. We'll get to it later; now let us begin by exploring the changing use of the word 'mass'. What is the origin of the word in English? It is rather fascinating. It derives from the Latin *massa* meaning a lump of dough, but sometimes also a lump of stuff generally (e.g., of metal). The Latin word derives from the Greek μᾶζα (*maza*) which meant both dough and barley bread. But now the plot thickens: there is a clear connection between μᾶζα and Hebrew *matzah*, unleavened bread eaten at Passover. There are interesting speculations as to whether the word is in origin Semitic or Indo-European.

Example 1. You are given a chunk of wood, matches, and scales. Question: how to measure the mass of smoke that will be created after you have burned the wood?

Aristotelian mass. If you have answered this question, then you are in disagreement with Aristotle and Aristotelians. For the Aristotelians, the question can have no definitive answer. Mass (or weight) is a property of substances (no distinction made between primary and secondary qualities). So different substances have different inherent weights. This conception is possibly influenced by biological origins of Aristotle's though (note: ὕλη means wood in Greek). Organic matter, as it grows or decays, does not preserve weight. It required later investigators to show how elements come and go in the process of growth or decay.

Newton's definition of mass. *The quantity of matter is the measure of the same, arising from its density and bulk conjointly.*

He appends this explication: Thus air of a double density, in a double space, is quadruple in quantity; in a triple space, sextuple in quantity. The same thing is to be understood of snow, and fine dust or powders, that are condensed by compression or liquefaction, and of all bodies that are by any causes whatever differently condensed. I have no regard in this place to a medium, if any such there is, that freely pervades the interstices between the parts of bodies. It is this quantity that I mean hereafter everywhere under the name of body or mass. And the same is known by the weight of each body, for it is proportional to the weight, as I have found by experiments on pendulums, very accurately made, which shall be shown hereafter. (*Principia*, Definition I)

Newton on inertial force. *The* vis insita*, or innate force of matter, is a power of resisting, by which every body, as much as in it lies, continues in its present state, whether it be of rest, or of moving uniformly forwards in a right line.*

Explication: This force is always proportional to the body whose force it is and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inert nature of matter, is not without difficulty put out of its state of rest or motion. Upon which account, this *vis insita* may, by a most significant name, be called inertia (*vis inertiae*) or force of inactivity. But a body only exerts this force when another force, impressed upon it, endeavours to change its condition; and the exercise of this force may be considered as both resistance and impulse; it is resistance so far as the body for maintaining its present state, opposes the force impressed; it is impulse so far as the body, by not easily giving way to the impressed force of another endeavours to change the state of that other. (*Principia*, Definition III)

Inertial force and quantity of matter are intrinsic properties. *The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.*

Explication: If it universally appears, by experiments and astronomical observations, that all bodies about the earth, gravitate towards the earth; and that in proportion to the quantity of matter which they severally contain; that the moon likewise, according to the quantity of its matter, gravitates toward the earth; that on the other hand our sea gravitates toward the moon; and all the planets mutually one towards another; and the comets in like manner towards the sun; we must, in consequence of this rule, universally allow, that all bodies whatsoever are endowed with a principle of mutual gravitation. For the argument from the appearances concludes with more force for the universal gravitation of all bodies, than for their impenetrability, of which among those in the celestial regions, we have no experiments, nor any manner of observation. Not that I affirm gravity to be essential to all bodies. By their *vis insita* I mean nothing but their inertia. This is immutable. Their gravity is diminished as they recede from the earth. (*Principia*, Rule III, Book III)

Interpretations of Newton's ideas. We see that Newton's definition only makes sense if we accept density as a primitive term. But how is it possible to understand and measure density without first taking care of mass and volume? So perhaps we can use the Second Law ($F = m \cdot a$) and define mass through force and acceleration. That was indeed Euler's idea: mass becomes a mere co-efficient in the formulation of the Second Law. But here again we face the question whether force can be understood prior to mass. Later physicists generally were even less friendly to Newtonian forces, than to irreducible mass. Finally, we may try to define mass as the number of material particles.

Mach's critique: Back to experience! We cannot put up with metaphysical concepts at the heart of physical theory. 'Quantity of matter' is obscure. Nor should we accept the existence of hypothetical atoms unavailable in experience. Nevertheless we have to establish that mass is a property of body independent of the environment it is present in (and so not to be associated with weight).

Imagine two isolated bodies A and B and assume that they are constituted in the exactly similar way. Let their accelerations be a_A and a_B. Then symmetry should tell us that accelerations will be numerically the same and oppositely directed (along the seam line). Now, it may be that the accelerations are determined by the sameness of shape or chemical composition, or indeed any other quality. But if this is not the case, then the property responsible for equal accelerations is nothing but mass.

Hence the definition: *All those bodies are bodies of equal mass, which, mutually acting on each other, produce in each other equal and opposite accelerations.*

Mach on scientific methodology. The purpose of science is to systematize observations for further *practical* purposes. We do not, and cannot, discover the ultimate blocks of reality. For what is reality? Just a collection of sensations. We necessarily represent in our discourse not the whole collection of sensations available to us, but a select fragment. There are no things: those that we call 'things' (windows, tables, men) are abstractions from our sensations.

Remark 2. On the nature of reality, observe a sharp contrast between Mach's and Helmholtz's positions.

Causation and explanation. Causal relations are products of habit (as in Hume). We routinely observe certain connections between event-types in time. After a while, the preceding events are elevated to the category of 'causes'. Psychologically, we may be committed to the presence of causes, since the events are apparently outside of our control. The scientific purpose of this is again management of experience: we are better equipped for prediction and control if we can describe the causal history. Again, observe the contrast with Helmholtz. Furthermore, our capacity for causal reasoning (the possession of the idea of cause) may be a matter of a *biological* feature of our race.

With a strikingly Kantian sentiment, Mach claims that experience is blind without our abstractions. Only by imposing our abstractions on (or importing into) the experience we make it intelligible to us. So the role of causation, among others, is not only prediction, but also explanation.

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