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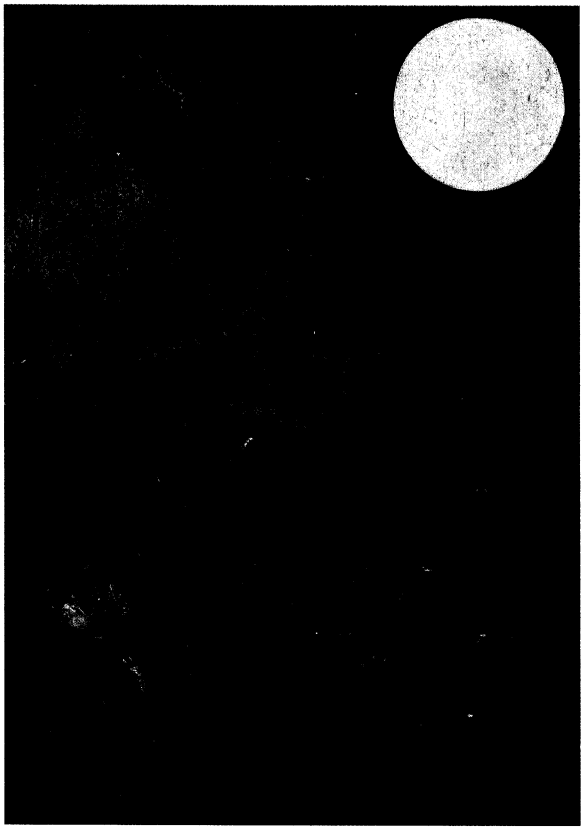

Edited by

W. H. NEWTON-SMITH

A Companion to the Philosophy of Science

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Mach

GEREON WOLTERS

Ernst Waldfried Josef Wenzel Mach was born 18 February 1838 in the Moravian village of Chrlice (near Brno), at that time part of the Austrian Monarchy, now the Czech Republic, and died 19 February 1916 in Vaterstetten (near Munich). He enjoyed a very successful career as an experimental physicist (the unit for the velocity of sound has been named after him). His importance for the philosophy of science derives mainly from his "historico-critical" writings (Mach 1872, 1883, 1896b, 1921). Mach studied mathematics and physics at the University of Vienna (1855–60, doctorate in physics 1860, his "Habilitation" (i.e., qualification to become a university professor) 1861) and his subsequent work was in the physiology of the senses. In 1864 he became professor first of mathematics and then (1866) of physics at Graz University; from 1867 to 1895 he was professor of experimental physics at Prague University; and in 1895 he took a chair in "Philosophy, especially the History and Theory of the Inductive Sciences" at Vienna University. In 1898 a stroke ended Mach's university teaching, but he was able to continue scientific work to a certain degree.

Mach's philosophical activities can be subsumed under the general heading of "anti-metaphysics." This means the attempt to make philosophy (i.e., epistemology) more scientific and science more philosophical by dismissing from ontology everything that cannot be shown to be empirically significant.

The anti-metaphysical reform of epistemology led Mach to a sort of phenomenalism with so-called neutral elements as the irreducible basis of all knowledge. Examples of elements are memories, imaginations, etc., as well as colors, sounds, heats, pressures, spaces, times, etc. They "are interconnected in manifold ways" (Mach 1886, p. 2) to complexes or clusters. Only these complexes, not the elements they consist of, are the objects of unreflected awareness. Those clusters of elements that display a certain stability may be called "things" or "bodies" for the sake of convenience. For the same reason they receive a proper name or predicate. Among the "things" one also finds one's own body. It is distinguished from other things particularly by the fact that the elements that constitute it are closely (mostly functionally) interconnected with elements like volitions, feelings, memories, etc. Because of its continuity, the "I" is the relatively stable complex of the elements that constitute one's body and the volitions, memories, etc. functionally connected to it. There is no strict borderline between one's "I" and the bodies, because bodylike complexes of elements too may vary according to their functional relationships to I-like elements; for example, a stick partly immersed in water is crooked when seen and straight when touched (ibid., p. 10). For Mach it makes no sense to ask what the stick *really* is.

Mach's approach contradicts realistic conceptions that conceive of elements as causally generated by "things"; it asserts just the reverse: that things are clusters of elements. Only those elements of thinglike complexes of elements that are regarded in their functional dependence on elements that constitute our own body may be called "sensations." So "a color is a *physical object*, as soon as we pay attention to its dependence on the illuminating source of light (other colors, heats, spaces, etc.). But if we pay attention to its dependence on the retina (or other bodily elements), the same color is a *psychological object*, a *sensation*" (ibid. p. 17).

On the other hand, Mach contradicts the idealistic project of constituting the world of objects out of subjective sensations. For Mach's elements are neither objective nor subjective. They are just there. These neutral elements are the "given" of Mach's positivism. What is called "objective" or "subjective" in the traditional sense is only a special type of functional relationship between neutral elements: a "subjective" relationship expresses a connection between "I-like" and bodylike complexes of elements, whereas an "objective" relationship refers to dependencies among those bodylike complexes themselves.

From Mach's epistemological "neutral monism," three important consequences are derived: (1) causality is nothing more than a functional dependence between elements; (2) there is no "substance" as carrier of properties, but only elements in more or less stable complexes; (3) the mind–body problem is a *pseudo-problem*, because there are no generic differences between elements. Only according to the type of the functional dependency of its elements might a complex of elements be called "physical" or "psychological."

Mach emphasizes (addition 1 of the 5th–9th German editions of Mach 1886) that working physicists may easily dispense with his epistemology. It is indispensable only in research on the psychophysical relationship. Accordingly, Mach's methodology is systematically independent of his epistemology, although it can be regarded as an application of it.

For Mach, science has two central features: (a) its "biological" function for humans, and (b) its essentially "historical" nature – i.e., the transience of its respective outlooks. Both features reveal the anti-metaphysical thrust of Mach's thinking.

Anti-metaphysics in Mach's biological conception of science consists in restricting science to the *description of facts*, for only facts provide the orientational stability needed for acting with differential survival value. But a totally descriptive science is only the ideal, but unattainable, final goal of science. For the time being one has to rely on hypotheses and theories ("indirect descriptions"), that, with scientific progress, should gradually be replaced by "direct descriptions." Note that Mach does not advocate sensualism; for not only observations qualify as facts, but also not directly observable items like phases of sound waves, the law of propagation of heat, or, most important, theoretical "principles" (e.g., the energy principle, the principle of inertia). Principles are not observed in nature, but "intuited" by imaginative power on the basis of intimacy with natural phenomena. They are selected according to their "economic" value (cf. below); they are "conventions," as Mach agrees with H. Poincaré (see CONVENTION, ROLE OF) (Mach 1883, p. 306).

Mach presents – again with anti-metaphysical intention – two fundamental rules of concept formation in empirical science: (1) distrust all concepts that do not actually

have observable referents; (2) exclude all concepts from science that in principle cannot have observable reference. From these rules follows a fundamental critique of all attempts to reduce empirically adequate conceptions to allegedly "deeper" theories whose concepts fail to have any observable referents in the domain in question. This leads Mach to a strict, *anti-mechanistic position* in physics. In this vein he ontologically rejected the existence of atoms and other invisible particles, and attributed, at best, instrumental value to mechanistic models of nonmechanical phenomena (e.g., the kinetic theory of heat). Only towards the end of his life does Mach seem to have given up his anti-mechanism (see Wolters, in Haller and Stadler 1988).

There is one more reason to consider science a "biological" endeavor: science is basically nothing else than a professionalized continuation of a particular form of everyday human survival activity – namely, observing nature and craftsmanship. This kind of activity has existed even since the dawn of of human cultural evolution.

The biological characterization of science has a variety of consequences. It follows, according to Mach, that we should adopt *theoretical instrumentalism*. The primary aim of science is not to tell us what the world as such is like, but rather to give us a successful explanatory and prognostic orientation. Only in a secondary sense does reliable orientation require correspondence to facts. It also follows that science correlates observables, and is thus based on, and restricted to, *empirical* quantities. The consequences of scientific theories have to match observations. In addition, for Mach, science is not only part of human cultural evolution, but also an activity that has itself to be described in *evolutionary terms*. Mach characterizes science (1905, ch. 10) as (a) "adaptation of thoughts to facts" (i.e., "observation") and (b) "adaptation of thoughts to each other" (i.e., "theory"). But he does not foreshadow the observation–theory dichotomy of logical empiricism, because he already emphasizes the theory-ladenness of observation (ibid., p. 120) as well as (in his "adaptation of thoughts to each other") a holistic theory conception (see LOGICAL EMPIRICISM and HOLISM). But not only the conceptual core of Mach's conception of science is evolutionary. The development of science, too, has to be described in evolutionary terms. Theories "fight their struggle for life no differently than the ichthyosaurus, the Brahman, and the horse" (Mach 1896a, p. 40 (dt.)). Finally, Mach's famous principle of economy is part of the biological characterization of science: first, in the rather external sense, that science saves experiences "by the reproduction and anticipation of facts in thought" (Mach 1883, p. 577). Internally, the principle of economy allows us to concentrate on selected features of the facts and requires their "completest possible presentment . . . with the least expenditure of thought" (ibid., p. 586). So simplicity and range become for Mach criteria for the assessment of theories (see SIMPLICITY).

History reveals science as (1) "unfinished, variable" (Mach 1872, p. 17). History is (2) of greatest value, because the study of the origin and development of ideas renders them familar to us in a similar way as if we ourselves had found and developed them. At the same time the understanding of origins (3) makes us more open to scientific progress, because a view whose origin and development we know "is never invested with that immobility and authority which those ideas possess that are imparted to us ready formed. We change our personally acquired views far more easily" (Mach 1896b, p. 5).

Although Mach has no recipe for bringing about scientific progress, the study of history offers a number of successful heuristic procedures: for example, (1) *analogy*

between different domains (e.g., the understanding of light waves as analogous to sound waves); (2) the "*principle of continuity*" (Mach 1883, p. 167), as the attempt to retain under varied circumstances, as much as possible, an idea derived from a special case (e.g., Galileo's discovery of the law of free fall by "continuing" the regularities observed with the inclined plane); (3) "*abstraction*" – that is, elimination of nonrelevant aspects in the case under question; and (4) "paradoxes" as strong incentives to bring a theoretical system into harmony once again.

Mach's thought has exerted great influence in both science and philosophy. His anti-mechanism, as well as his rules of concept formation (particularly the critique of "absolute space") stimulated Einstein in his theories of special as well as general relativity (see EINSTEIN). Posthumously published texts ascribed to Mach that reject relativity were almost certainly forged (see Wolters 1987). In recent years too, Mach's principle in cosmology, which had fallen into disregard already in the 1920s, has been successfully revived in a new interpretation. Mach's strict empiricism was instrumental for the Copenhagen Interpretation of quantum mechanics (see QUANTUM MECHANICS).

In philosophy, logical empiricism saw itself, as far as its empiricism was concerned, as continuing the work of Mach. R. Carnap's phenomenalistic constitutional system in his *Der logische Aufbau der Welt* is directly influenced by Mach's positivism. Mach's anti-metaphysics played an important motivational role for the anti-metaphysics of the Vienna Circle. Its external, educational activities were carried out by the officially registered Ernst Mach Society.

But Mach's philosophy of science, with its emphasis on the biological function of science and the transient historical character of all theorizing, with its insight into the theory-ladenness of observation as well as its holism, seems to be less close to mainstream logical empiricism (with the exception of O. Neurath) than it is to the critics of logical empiricism since the 1960s.

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