PREFACE

Ernst Mach was a physicist, sense-physiologist, and philosopher and, after the death of Helmholtz, probably the last individual to make significant professional contributions to all three areas. Because of his broad training, Mach was also one of the first scientists to suggest that the results of these special disciplines ought to harmonize with one another in a metascientific natural philosophy, in which, for example, the data of psychology would be valued equally with the data of physics. In particular, Mach believed there should not be a gulf between a physical science of objects and motions and the psychological science of sensations and thoughts.

In the seventeenth century, dualism had been proposed as a way out of the dilemma, making sensations into subjective, secondary qualities which were caused by interaction with a sensationless world of matter and motion, like that proposed by Galileo and Descartes. Henceforth, the scientist could ignore the quality of experience as such and concentrate on mathematical models of the primary qualities of nature: bulk, number, shape, and motion.

By Mach's time, dualism had broken down and led either to idealism or materialism. Berkeley's idealism, for example, proposed that the entire world consisted of sense qualities, either of human beings or of God, who has sensations of objects even when human beings do not. By comparison, in materialism, sensations and mental phenomena had no reality and it was hoped that particles and forces would eventually explain them away. At the beginning of the nineteenth century in Vienna, materialism was at its height. But Mach rejected both of these alternatives. His goal was a natural philosophy that could bring the abstractness and idealization of physics into harmony with the concreteness of sensations. This alternative conception was later called "neutral monism" by Bertrand Russell.

Philosophers are familiar with Mach as a forerunner of the Vienna Circle, that group of mid-twentieth century scientist-philosophers that included Rudolf Carnap, Moritz Schlick, Otto Neurath, and others loosely called logical positivists. Positivists were thought to hold to a "verification principle" according to which statements unverifiable in principle were branded "metaphysical" and removed from scientific discussion. It can easily be shown that Mach neither believed in this principle nor did his own physical and philosophical speculations measure up to it. So if the verification principle were the measuring stick, Mach was not a positivist, at least not a logical positivist.

I became acquainted with Mach's writings while I was extremely hostile to positivism of any sort, and I read his *Analysis of Sensations* several times before I could think seriously about it. Indeed, it was really only after considering Mach's

development in the context of German philosophy and science from Kant, J.F. Herbart, G.T. Fechner, and Johannes Müller that I realized the usual positivist reading of Mach was in error, a result of emphasizing "Mach the positivist philosopher" over Mach the scientist and natural philosopher.

Mach began his physics training as a straightforward realist: believing in a world *really* consisting of matter moving in space and time, independent of human sensory powers. Reading Kant as a fifteen-year-old forced Mach to doubt the application of spatial and temporal concepts to the world beyond the conditions of human perception, and Mach himself began to doubt the *Ding an sich* or a permanence behind the appearance of matter.

In J.F. Herbart's *Allgemeine Metaphysik*, which he studied as a young man, Mach found an example of a philosophical construction of space and matter out of unextended elementary forces or energies. But it was Mach's own work in psychophysics and the influence of G.T. Fechner that convinced him the real constituents of the world were concrete qualities and functions. It was then but a short step from Fechner and Herbart to his own *Elementenlehre*.

Such was the great axis on which Mach's thought moved: reconciling psychophysics with physics. But whereas Fechner and others had tried to make psychophysics look more like physics, Mach attempted a *sense-physiological critique of physical concepts*. Mach thought the spatial and temporal form of physical principles made concessions to the human need to visualize events in a kind of sensory continuum, like the visual or auditory fields, which later could be dropped in a more mature science. Mach's historico-conceptual studies of mechanics and thermodynamics were attempts to set the most general and abstract results free from their historical background as well as from visualizable picture-thinking.

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