Introduction

A New Mach for a New Millennium

JOHN PRESTON

Mach's Career and Principal Publications

Ernst Mach is, in my view, one of the greatest of a very significant and original group of thinkers: the philosophising scientists of the late nineteenth and early twentieth centuries. Although Mach did not think of himself as a philosopher, it is the more philosophical parts of his published works that continue to attract the most attention. Mach's ideas, their reception, and the trajectory of Mach scholarship since the late nineteenth century unfolded as follows.

Mach studied physics at the University of Vienna from 1855, becoming skilled in the techniques of the physical laboratory there. He received his doctorate in 1860, taking up his first professional appointment in physics in 1861. His first published book was a compendium of physics for medical professionals, but because Mach had by then developed an interest in physiology and psychology, it was followed in the same year (1863) by a series of lectures on psychophysics. His experimental investigations covered a variety of phenomena, including the Doppler effect, the measurement of blood pressure, and acoustics.

In 1864, Mach moved to take up a position at the University of Graz, where he again taught a variety of courses, including psychophysics, having been directly influenced by the founder of that discipline, Gustav Theodor Fechner. He gave many popular-scientific lectures, at least some of which were to girls and women at Graz's recently established *Mädchenlyzeum* ('Lyceum for Girls'). Over the next few years, he published a series of papers setting out and investigating the phenomena we now call 'Mach bands' (the apparently paradoxical exaggeration of the contrast between the edges of patches of different shades of grey that are next to one another). And as a result of his investigations into the physiology of sound sensation, especially in musical appreciation, he published *Einleitung in die Helmholtz'sche Musiktheorie: Populär für Musiker dargestellt* (*Introduction to Helmholtz's Music Theory, Popularly Represented for Musicians*) in 1866.

By 1867, though, he had moved on to Prague, as a professor of experimental physics. His groundbreaking studies of motion perception were published as

Grundlinien der Lehre von den Bewegungsempfindungen (*Fundamentals of the Theory of Movement Perception*) in 1875.

While still in Prague, Mach published a short book, *Die Geschichte und die Wurzel des Satzes von der Erhaltung der Arbeit* (1872, translated as *History and Root of the Principle of the Conservation of Energy*). Amply philosophical, this served to present many of his most important ideas in embryo. It can be thought of as the first in his series of distinctive 'historical-critical' studies, which aim to exhibit the historical contingency of the state of science in Mach's time, as well as the presumptuousness of the 'mechanical world view' which Mach, by that time, had come to be so sceptical about.

Mach's background in ballistic experimentation made him well-placed to conduct a series of experiments on shock waves during the second half of the 1870s and much of the 1880s. From these experiments we ultimately derive several items of physical terminology, including our way of referring to the speed of sound as 'Mach 1'. His remarkable study of the history of mechanics, *Die Mechanik in ihrer Entwickelung historisch-kritish dargestellt* (translated as *The Science of Mechanics: A Critical and Historical Account of Its Development*), the first of his books to include a subtitle referring to his 'historical-critical' method of exposition and critique, was published in 1883. It featured Mach's full critique of Isaac Newton's conceptions of space and time.

Although Mach had shelved his own manuscript *Beiträge zur Analyse der Empfindungen* (*Contributions to the Analysis of the Sensations*) for twenty years after Fechner had reacted badly to it, it was published in 1886, and later fleshed out to become a much larger volume, *The Analysis of Sensations and the Relation of the Physical to the Psychical*. Addressed principally to biologists and aiming at showing how physics and the physiological sciences could learn from one another, it has become Mach's best-known book, although it must be said that this has somewhat distorted his reputation in the process.

Problems in Prague, together with the suicide of one of his sons, dictated a move for Mach, and in 1895 he returned to Vienna, where he took up a new chair as Professor of the History and Philosophy of the Inductive Sciences. His *Popular Scientific Lectures*, testifying to the vast range of his interests and to his great pedagogical abilities, were published in 1895.

From the 1860s onwards, the tireless work of Ludwig Boltzmann had vastly increased the reputation of statistical mechanics, the kinetic theory of gases, and the atomic hypothesis. Mach's opposition to the mechanical world view and to the atomism associated with it engaged him in controversy with Boltzmann and leading figures in physics at his own alma mater, the University of Vienna. His 1896 book *Die Prinzipien der Wärmelehre, historisch-kritisch entwickelt* (translated as *Principles of the Theory of Heat: Historically and Critically Elucidated*, but not until 1986), which Mach's biographer John Blackmore memorably called 'probably the only book ever

written on thermodynamics with over a dozen chapters overtly on philosophy', was largely directed against Boltzmann.

Mach's career as an experimenter and lecturer was cut short in 1898 when he suffered a stroke which partially paralyzed him. But he continued to work, revising his published books for new editions and incorporating some of his lectures on philosophy of science into his 1905 book *Erkenntnis und Irrtum: Skizzen zur Psychologie der Forschung* (translated as *Knowledge and Error: Sketches on the Psychology of Enquiry*), which he thought of as the mature statement of his epistemology.

Although Boltzmann's suicide in 1906 meant the loss of Mach's most illustrious opponent, the Berlin physicist Max Planck initiated a fierce debate with him towards the end of the twentieth century's first decade. Mach found himself forced to defend his widely based epistemological stance against Planck's rival conception of an acceptable scientific world view, a conception derived much more exclusively from contemporary physics.

Mach died in 1916, but his book *The Principles of Physical Optics* was seen through to publication by his son, Ludwig, in 1921.

In recent years, Mach's main books have also been republished in German (by Xenomoi in Berlin: www.xenomoi.de/philosophie/mach-ernst), with new introductions, in the series *Ernst Mach Studienausgabe*, edited by Friedrich Stadler, together with Michael Heidelberger, Dieter Hoffmann, Elisabeth Nemeth, Wolfgang Reiter, Jürgen Renn, and Gereon Wolters. The volumes are:

> *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen* (1886), edited by Gereon Wolters (2008).
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> *Erkenntnis und Irrtum* (1905), edited by Elisabeth Nemeth and Friedrich Stadler (2011).
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> *Die Mechanik in ihrer Entwickelung. Historisch-kritisch dargestellt* (1883), edited by Gereon Wolters and Giora Hon (2012).
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> *Populärwissenschaftliche Vorlesungen* (1896), edited by Elisabeth Nemeth and Friedrich Stadler (2014).
>
> *Die Prinzipien der Wärmelehre* (1896), edited by Michael Heidelberger and Wolfgang Reiter (2016).
>
> *Die Prinzipien der physikalischen Optik* (1921), edited by Dieter Hoffmann and Josef Pircher (2020).

Mach's Influence

Mach was already enormously influential across scholarly fields and cultural fields during his own lifetime. His works evoked reactions from fellow scientist–philosophers such as Heinrich Hertz, Wilhelm Ostwald, Georg Helm, Ludwig Boltzmann, William James, Sigmund Freud, Charles Peirce,

Oswald Külpe, Jacques Loeb, Pierre Duhem, František Wald, Karl Pearson, W. K. Clifford, W. S. Jevons, Bronisław Malinowski, Ewald Hering, Carl Stumpf, Max Planck, and Albert Einstein. The strength of Mach's influence among Russian thinkers was testified to by the fact that V. I. Lenin felt it necessary to critique it in his 1909 book *Materialism and Empirio-Criticism* in order to ensure that Russian Marxists should not be tempted by a Machian perspective which, as a thoroughly modern and scientifically informed perspective, represented a serious competitor to 'dialectical materialism'. At the same time, in more purely academic philosophical and cultural circles, Mach was influential on figures such as Edmund Husserl, Ernst Cassirer, Paul Carus, Hans Kleinpeter, Richard Avenarius, Wilhelm Jerusalem, Wilhelm Schuppe, Heinrich Gomperz, Friedrich Adler, Joseph Petzoldt, Hans Cornelius, Philip Jourdain, and Robert Musil.

In the twentieth century's second decade, following Mach's death, his philosophical work influenced two new groups of thinkers. The first group featured two of the founders of analytical philosophy: Bertrand Russell and Ludwig Wittgenstein. The second group, working in the second half of that decade, included the figures who would go on to form the Vienna Circle, perhaps most notably Moritz Schlick and Philipp Frank. It was thinkers from that Circle who, taking Mach as one of their central inspirations, cemented his reputation in the history of philosophy and established what we might think of as the 'received view' of his philosophical works. Because of the new ways in which logic and philosophy were themselves being conceived, along with an antipathy to 'psychologism' and an increasing tendency to think of science in formal terms, this received view portrayed Mach as something like a paradigm case of a *pre*-logical positivist. Even outside the more narrow confines of the Vienna Circle, though, Mach also had other admirers and defenders during this same era, such as P. W. Bridgman, B. F. Skinner, Robert Bouvier, Hugo Dingler, C. B. Weinberg, and Richard von Mises.

It was positivist readings of Mach which went on to dominate what we might think of as a third phase in the reception of his ideas, a phase beginning in the 1950s and featuring thinkers who reacted strongly against positivism, such as Karl Popper (and his followers), Gerald Holton, Francis Seaman, Peter Alexander, and John Blackmore. These readers thought of Mach as a paradigm phenomenalist, sensationalist, foundationalist, and instrumentalist, and for them such views betokened the untenability of his philosophy. In this era (1950s–1970s), Erwin Hiebert, Stephen G. Brush, Wolfram Swoboda, Floyd Ratliff, Otto Blüh, and Larry Laudan are notable examples of those who were beginning to develop a more historically informed and sympathetic take on Mach.

The complexion of English-language Mach studies began to change more rapidly in the 1970s. Paul Feyerabend, having rediscovered in the mid-1970s the Mach he had read significantly earlier, began resuscitating his reputation.

In the full flow of his own renunciation of Popperian views, Feyerabend took particular aim at accounts of Mach produced by followers of Popper and Imre Lakatos. His earliest published paper on this subject also includes a nod to work on Mach by Laudan, a contribution of whose in the mid-1970s might be grouped with Feyerabend's in this respect.

Since then, there has been something of a flowering of Mach scholarship, with Feyerabend's increasing encouragements lying alongside continuing Mach-related publications in the 1980s from Blackmore, Gerald Holton, and Erwin Hiebert, but being joined by important work from new figures such as Gereon Wolters, Rudolf Haller, Klaus Hentschel, Henk Visser, Michael Matthews, John Norton, Aldo Gargani, and Brian McGuinness, who, having brought Mach's *Erkenntnis und Irrtum* to publication for an English-speaking audience in 1976, did the same for his *Wärmelehre* a decade later. In the 1990s, the new voices included Friedrich Stadler, Andy Hamilton, S. G. Sterrett, Julian Barbour, Ursula Baatz, Michael Stöltzner, and, in the first decade of the twenty-first century, Dario Antiseri, Karl Hayo Siemsen and his son Hayo Siemsen, Paul Pojman, Michael Heidelberger, Jaakko Hintikka, Robert DiSalle, and Gary Hatfield.

The most recent 'turn' in Mach scholarship, though, can be thought of as largely due to the work of Erik C. Banks, to whose memory this volume is dedicated. Erik received his undergraduate degree from Bennington College, Vermont, and his PhD from the City University of New York in 2000 for his thesis 'Ernst Mach's World Elements', with Arnold Koslow as his dissertation advisor. This was based on his study of Mach's *Nachlass* at the Deutsches Museum, Munich, during the summer of 1999. It was subsequently published as his first monograph, under that same title (Banks 2003). In 2006, Erik joined the faculty at Wright State University, Ohio. He published several very important articles on Mach, and in 2014 his second monograph, *The Realistic Empiricism of Mach, James, and Russell: Neutral Monism Reconceived*, was published by Cambridge University Press.

Erik's work as a whole situates Mach firmly in the history of the sciences to which Mach contributed (notably physics, physiology, and psychology), as well in the history of philosophy. It also displays great potential for showing how Mach's work might contribute to contemporary debates in, for example, metaphilosophy and naturalistic metaphysics, philosophy of mind, and philosophy of science (integrating history and philosophy of science).

Erik died unexpectedly in August 2017. He was originally my co-editor on this volume, and I am deeply grateful to him for his inspiration and for all of the work he put into it. A small indicator of his great dedication to Mach and to the production of this volume is the fact that he had already finished his chapter for the volume, more than three years before it goes to press.

Erik's work undoubtedly contributed to the recent renaissance of interest in Mach. The Ernst Mach Centenary Conference of June 2016, organised by the

Vienna Circle Institute, University of Vienna, and the Austrian Academy of Sciences, featured a host of scholars of many aspects of Mach's work. Its very substantial proceedings were published in 2019 in two volumes edited by Friedrich Stadler.

The Volume's Papers

In this volume, Alexandra Hui concentrates on Mach's work in psychophysics, surveying the many ways in which, using a great variety of resources, including multimodal descriptions, he described psychophysical experiences. She compares the ways in which he discussed psychophysics in his popular lectures, scientific publications, and personal correspondence, and she argues that Mach's celebrated techniques of presentation and argumentation went far towards cultivating a psychophysical imaginarium, a space devoted to the cultivation of the imagination.

Richard Staley, too, focuses on Mach's work in psychophysics, showing how that dovetailed with his activity in physics. He takes up Albert Einstein's remark that the influence of Mach's writings on the evolution of the sciences was such that even his opponents were unaware how much of Mach's thinking they had absorbed 'with their mother's milk'. Staley argues that Mach's studies of sense perception sought to recover basic perceptual experience sensitive to the relations between different sensations of space and time, helping to initiate Mach's work on physical space and time. He shows how Mach's studies of mass, action and reaction, and inertia were not only conceptually linked, but also derived and emerged from perceptual studies and bodily experience, exhibiting the way in which Mach's ambition was to find an epistemology which could examine *all* human experience.

Daan Wegener's chapter addresses various aspects of the nineteenth-century history of energy conservation and emphasises the centrality of the law of conservation of energy within Mach's work, but also connects that law with more general concerns in Mach's philosophy of science via his distinctive take on the nature of concepts and their meaning.

Mach's *Knowledge and Error* includes much material on the idea of analogy, prefigured by an important article of 1902. These discussions of analogy in ordinary life and in natural science are the subject of the chapter by S. G. Sterrett. She shows how rich and subtle was Mach's account, which distinguished analogy from similarity in a way that carried over to the natural sciences, and also in a way which brings to prominence the *value* of analogy, which is now being rediscovered in disciplines such as archaeology. For Mach, analogy in natural science is a relation between systems of concepts, and the use of this method can be powerful in extending knowledge, since science is more variegated than just scientific enquiry into the unknown. Where

opportunities to use analogy are wasted, the scientist can be left clinging to an inadequate theory.

How Mach stood with respect to both the American Pragmatist tradition and, more widely, the very idea of a pragmatist philosophy has been a subject of renewed interest in recent years. In this volume, Thomas Uebel's contribution argues that Mach's historicist naturalism can be considered an original form of pragmatism. For Uebel, Mach's principle of scientific significance and its background conception of knowledge deeply exemplify the rejection of scepticism and acceptance of fallibilism which characterise pragmatism.

Focusing more specifically on the relationship between Mach and one of the leading pragmatist thinkers, William James, Alexander Klein shows that this influence ran both ways. In experimental matters concerning volition and the feeling of muscular effort, it was James who changed Mach's mind. Mach, for his part, might have exerted a modest influence on James's philosophical outlook but, surprisingly, philosophical issues only motivated a small fraction of their intellectual exchanges.

The relationship between Mach's thought and that of an apparently more intellectually distant near-contemporary, Friedrich Nietzsche, has also come under scrutiny in recent years. Pietro Gori here provides a thorough account of this association, arguing that the consistency of their views is substantial. Despite their interests being different, both Mach and Nietzsche were concerned with the same issues about our intellectual relationship with the external world, dealing with the same questions and pursuing a common aim of eliminating worn-out philosophical conceptions. Gori shows that not only did they converge on what we now know as the problem of realism versus anti-realism in the philosophy of science, but also they both rejected 'representational' (realist) conceptions of science in favour of a certain sort of pragmatic anti-realism, whose focus was on the role science plays as a means of orientation.

Pragmatism also figures here in the contribution of Lydia Patton, who presses for a far fuller and more robust understanding of Mach's notion of the 'economy of science' than the one associated with the received view. She argues that Machian 'economy' appeals not only to the continuity between scientific experiences and concepts, but also to the increasing complexity of scientific concepts, emphasising both continuities between experiences on the one hand and areas of divergence that promote the branching of scientific concepts and methods on the other. She examines the roles of abstraction, pragmatism, and history in Mach's economy of science, arguing that his overarching concern, in accounting for the role of the scientist in the economy of science, is with what she calls the pragmatic history of the experiencing and creative knower, rather than with exclusive, reductive phenomenological or biological explanations.

In a related vein, Luca Guzzardi here analyses the relation that two important doctrines of Mach's epistemology – his scheme of 'elements' and his idea of the economy of thought – bear to his 'historical-critical' approach. He argues, not only against the received view, but also going further than scholars such as Erwin Hiebert, that there is a more profound, structural relationship between Mach's conception of history and the anti-metaphysical remarks which open *The Analysis of Sensations* and introduce his scheme of elements. Guzzardi also proposes that recognising this can afford novel insights into Mach's doctrine of the economy of thought.

The ways in which Mach's work was understood and used by the Vienna Circle are examined in this volume first by Friedrich Stadler. Stadler begins by detailing the reception of Mach in what Rudolf Haller called the 'first Vienna Circle' (1907–1912), then moving on to its reception by the Vienna Circle proper (1924–1936). With a wealth of material, he shows how Mach influenced nearly all the members of the Circle in his capacity as an empiricist, a critic of metaphysics, and an advocate of the unity of science. But Stadler also argues that Mach's influence is somewhat bifurcated, with certain logical empiricists admiring him for overcoming an old-fashioned aprioristic philosophy and for reformulating an anti-Kantian empiricism, while others were more appreciative of his epistemological and methodological incentives and his conception of the unity of science.

Michael Stöltzner then compares the reception of Mach's work in Austria with its reception in Germany, arguing that the stricter, German interpretation of Mach finally prevailed. He points to a discrepancy between Mach's own conceptions of causality and natural laws and the less generous ones then popular among German physicist–philosophers, who also tended to think of Mach's scheme of elements as phenomenalism. In the light of the new physics of relativity and quantum theory, both based upon abstract principles, Mach's attempt to supply a physiological foundation of physical quantities appeared unattractive, and his epistemological principles (such as economy) were stripped of their biological and physiological bases. The Vienna Circle's eventual choice of the name 'Logical Empiricism' over 'Logical Positivism' suggested that positivism (associated with phenomenalism) had been superseded by the broader framework of empiricism, albeit a framework which still allowed the figures in question to pay tribute to Mach in a general way.

The first chapter of Mach's book *The Analysis of Sensations* (originally published in 1886, but then again in new and much-expanded editions up until 1906) undoubtedly formed much of the basis of the 'received view' and its association of Mach with phenomenalism, sensationalism, and positivism, and it has been something of a flypaper for Mach's critics. In his paper here, John Preston examines in particular the opening chapters of that book and tries to show that there is scope to read it in a non-phenomenalist way. The project of Mach's book, he argues, was to supply something which would allow

the unification of physics, physiology, psychophysics, and psychology. The resulting 'scheme of elements', inspired by Mach's work in psychophysics, was meant to identify 'elements' which stand in relations that both the physical sciences *and* psychological sciences could examine. Mach's monism, on this account, is a proposal from within science that offers a non-metaphysical ontology, an ontology which allows very different kinds of science to investigate epistemically accessible features of reality.

Erik C. Banks did a great deal to revive the way of thinking about Mach's work that Bertrand Russell and William James shared – the idea of 'neutral monism' – and his chapter for this volume builds on that proposal, showing along the way the inferiority of the received view of Mach as a crude positivist. Erik argues that this received view is a myth, and that Mach should rather be counted as an ancestor of the kinds of realism developed by the American 'New Realists' in the early twentieth century, which then developed in the work of Wilfrid Sellars, Grover Maxwell, and Herbert Feigl. Erik's chapter ends by ranging a non-panpsychist version of this 'Russellian monist' perspective against the work of contemporary figures such as Saul Kripke, David Chalmers, and Galen Strawson, and envisaging a revival of Mach's ideas that would parallel the way in which Russell's ideas in the philosophy of mind have recently been revived.

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Ernst Mach's Piano and the Making of a Psychophysical Imaginarium

ALEXANDRA HUI

> . . . we have to complete observed facts by analogy.
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> —Mach (1886, p. 13)

In the summer of 2018, I revisited Professor Mach. It had been over a decade since I'd made my way up the wide stairs and down the halls of the Deutsches Museum in Munich to the light-filled reading room of the museum's archives. This time, I passed Hermann von Helmholtz's Steinway piano on the stair landing. The archives had also acquired more of Ernst Mach's unpublished writings. I was eager to examine these, and I found re-engaging with the materials I had studied so carefully before to be something like visiting an old friend. Here were Mach's careful drawings of the inner ear bones. There was his quickly jotted recipe for risotto Milanese.

In the ten years since I had completed that project on nineteenth-century psychoacoustics and music, the history of science scholarship has crystallised its engagement with how things, phenomena, and concepts become objects of enquiry. Scholars frame this as how scientific objects come into being (Rheinberger and Fruton 1997; Daston 2000; Landecker 2007). In my own research, I'm interested in the phenomena that occur prior to the scientist's engagement with objects of enquiry. That is, I'm curious about the sensory perceptual processes that in turn frame the scientist's approach to and eventual understanding of scientific objects. The investigative object's coming into being is the culmination of an earlier crystallisation of the investigator's individual sensory perceptual framework.

I begin with the assumption that hearing is historical. That is, not only have sounds changed over time, but how individuals have heard them, what elements they found to be meaningful, and so on, have also changed over time. From there, we can begin to think about how the scientific ideas about hearing are both a clue to their developers' – the scientists' – own hearing and how they also altered their ways of hearing. I think we can presume – or at least I do – that, for the scientists, the process of studying sound and the sensory perception of it not only created new knowledge, but also altered the scientists' very perceptual frameworks. They altered their own bodies. Then, as