

Vienna Circle Institute Yearbook

Friedrich Stadler
Editor

Ernst Mach – Life, Work, Influence



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Ernst Mach – Life, Work, Influence

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Editorial

Ernst Mach (1838–1916) ranks among the most significant natural scientists and philosophers of the nineteenth and twentieth centuries. In physics, he paved the way for Einstein’s theory of relativity and was sceptical about Boltzmann’s atomism; in biology, psychology, and physiology, he pioneered with an empiricist and “gestalthaft” “Analysis of Sensations”; in philosophy of science, he served as a model for the Vienna Circle with the Ernst Mach Society, as well as initiated an integrated history and theory of science. His influence extends far beyond the natural sciences—to the Vienna Medical School and psychoanalysis (R. Bárány, J. Breuer, S. Freud), to literature (“Jung Wien,” R. Musil), to politics (F. Adler, Austro-Marxism and the Viennese adult education), to arts between futurism and minimal art, as well as to social sciences between the liberal school (J. Schumpeter, F. A. von Hayek) and empirical social research (P. Lazarsfeld and M. Jahoda). In today’s pedagogy, his genetic theory of learning is just as respected as his method in historical epistemology. Mach’s international impact already showed during his lifetime, in American pragmatism (W. James) and French conventionalism (P. Duhem, H. Poincaré). In 2016, on the occasion of the centenary of Ernst Mach’s death, the Institute Vienna Circle organized an international conference on the life, work, and influence of this scientist and philosopher, who worked at the University of Vienna and the Austrian Academy of Sciences for many years and who exerted significant influence on several generations of scholars and scientists, as well as of cultural and political agents. The main goal was to make a critical inventory of Mach’s lifework in line with state-of-the-art research and historiography.

The Ernst Mach Centenary Conference, June 15–18, 2016, was organized by the Institute Vienna Circle, University of Vienna, and the Austrian Academy of Sciences. This was certainly the biggest international conference dealing with the life, work, and influence of one of the most fascinating men, as a scholar and scientist with impacts up to the present.

We were pleased to have received an enormous amount of submissions from all over the world, from which the Program Committee chose some 60 papers, so that in addition to the invited speakers there was a presentation of nearly 90 papers in four parallel sessions, including three plenary lectures. A selection of

these talks in English is presented in this volume. Another set of papers in German is being published at the same time by Springer in the series “Veröffentlichungen des Instituts Wiener Kreis,” entitled *Ernst Mach – Leben, Werk und Wirkung*.

It was not by accident that this conference took place also on the occasion of the 25th anniversary of the Institute Vienna Circle as a nonprofit society and the 5th anniversary of the same Institute as a Department (subunit) of the Faculty of Philosophy and Education of the University of Vienna. Pleasingly, also the Vienna International Summer School—Scientific World Conceptions (USS/SWC)—has been active since its inception in 2001. As it is well known, Mach was one of the most important precursors of the later Vienna Circle around Moritz Schlick, which was also acknowledged by the naming of the “Verein Ernst Mach” (Ernst Mach Society) in parallel. This was only one reason why the Institute Vienna Circle served as the main local organizer for this huge event. In this regard let me thank again Sabine Koch and Robert Kaller, together with the members of the organizational staff (Josef Pircher, Olga Ring, Saskia Haber, and Eren Simsek).

One day before the official opening, the conference was started with a public lecture in the main building of the University of Vienna (Wiener Vorlesungen, organized by the City of Vienna) with a panel discussion on Mach’s undeniable significance for the relation between natural, cultural, and social sciences, especially his contributions toward an interdisciplinary approach in the age of a growing specialization and differentiation in the sciences was on the agenda. In this regard the historical and empiricist conception of his “neutral monism” opens still further developments and innovations. Independently, Mach’s significance in physics is still alive with the naming of the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, in Freiburg/Br. (Germany), where his archives were located before its transfer to the German Museum in Munich. It is not possible to focus on the numerous contributions to both proceedings, which are dealing more or less with most of these aspects of Mach’s lifework, mainly from a critical and present point of view.

I am grateful to the co-organizers and sponsors of the Centenary Conference: the University of Vienna, especially to the Rectorate and to the Deans of the seven faculties for their support of this representative conference, above all the Faculty of Philosophy and Education as the leading organizational unit, with its Dean, Elisabeth Nemeth. Furthermore, I thank Anton Zeilinger, the President of the Austrian Academy of Sciences, who enabled the cooperation and co-hosting of the conference. This was plausible given the fact that Ernst Mach was a professor at the University of Vienna and also a long-term member of the “Kaiserliche Akademie der Wissenschaften” (Imperial Academy of Sciences). Therefore, the conference ran under the auspices of Rector Heinz Engl and President Anton Zeilinger. Pleasingly, the ÖAW had established a new “Commission for the History and Philosophy of Sciences,” where Mach is one of the topics to be investigated following his historical approach in the philosophy of science. Last but not least, it was the pleasing cooperation with Johannes Feichtinger and his collaborator, Cornelia Hülmbauer, from the Institute of Culture Studies and Theatre History of the ÖAW that facilitated a smooth and productive planning and organization. It is not by accident that this

Institute is running the so-called Ernst Mach-Forum for the sciences in dialogue. In this regard it is worth mentioning that the Austrian Agency for International Cooperation in Education and Research (OeAD) is awarding annually a worldwide Ernst Mach stipend.

Ernst Mach was also a professor at the Charles University of Prague (where he had served as a Dean and Rector before the division in a German and Czech university). In this regard we could experience a continuous appreciation of Mach in Czechoslovakia, where in February 2016 another commemorative plaque was unveiled in the centre of Prague by the Czech and European Physical Society, in addition to the already existing memorial site at Mach's birthplace in Chrlice near Brno. In this context, special thanks go to Martin Cernohorsky and his team in Brno for all these initiatives (e.g., the recurring "Ernst Mach Days") and their cooperation with our conference by contributing papers and the cultural tour to Mach's birthplace and to the beautiful City of Brno at the end of the conference.

Another cooperation was organized by Anastasios Brenner from the University of Montpellier, a symposium on Mach, Pierre Duhem, and French philosophy of science as part of the conference, also on the occasion of the centenary of the death of this renowned French philosopher-scientist. Furthermore, we are looking forward to another promising cooperative project, the electronic publication of Mach's correspondence at the *Leopoldina* in Halle/S. (Germany) conducted by Klaus Hentschel.

In this context I want to refer to the running "Ernst Mach Studienausgabe" (Ernst Mach Study Edition) published by the small Berlin publisher Xenomoi Verlag, for the publication of Mach's six main books in German to date.

In the meantime, we had to mourn the death of three prominent Mach scholars who passed away during the preparation of the proceedings: Erik C. Banks, Hayo Siemsen and his father, Karl Hayo Siemsen. These colleagues contributed significantly to the research on Mach between epistemology and genetic pedagogy. We are honored that their last manuscripts are being published in this volume as a sort of testimony of their unique expertise in this field.

The publication of both volumes of the proceedings was realized with the help of Robert Kaller and Josef Pircher, to both of them whom I am grateful for their continuous collaboration. Thanks go also to the representatives and the production team of Springer Publishers.

Vienna, Austria
October 2018

Friedrich Stadler

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Part I
Mach and Austrian Philosophy

Chapter 1

Only a Philosophical “Holiday Sportsman”? – Ernst Mach as a Scientist Transgressing the Disciplinary Boundaries



Friedrich Stadler

Abstract Ernst Mach was already an international successful experimental physicist and scientist, when he, after professorships for Mathematics and Physics in Graz and Experimental Physics in Prague, took over the chair for “Philosophy, particularly for the History and Theory of the Inductive Sciences”, at the University of Vienna in 1895. This turn from the natural sciences to philosophy was really an exception in the academic field.

Given his strong as well as controversial history of influence in philosophy and in the sciences Mach’s own pessimistic statement about the emergence of aprioristic currents at the beginning of the twentieth century is surprising and in need of an explanation.

The article deals with Mach’s appointment in Vienna and Mach’s autobiographical fragments on his relation to academic philosophy from a today’s point of view. It appears that Mach can be regarded as a pioneer and predecessor of a topical “historical epistemology”, “history and philosophy of science”, and above all as a theorist and practitioner of inter- and transdisciplinarity. If he is to be regarded a philosopher, it is mainly in the context of naturalism, pragmatism and common sense philosophy – as general theory of research.

Which were the motifs for Mach, the passionate natural scientist (*Naturforscher*), who saw himself lifelong as a mere “holiday sportsman” (“Sonntagsjäger”) in philosophy, nevertheless to take over this important and contested chair in Vienna – a chair, which formed the basis for his successor Ludwig Boltzmann and Moritz Schlick as the founder of the Vienna Circle?

In order to answer this question one has to go back to Mach’s intellectual development, esp. to his key experience with the reading of Kant’s *Prolegomena*, the influence of the Kantian Eduard Beneke, as well as the philosophical commu-

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nication with his contemporaries: e.g., with Franz Brentano, Wilhelm Jerusalem, Theodor and Heinrich Gomperz, including Pierre Duhem and William James – which shows the family resemblance with French conventionalism and American pragmatism. At least we realize a pluralistic reception of Mach also within the Vienna Circle of Logical Empiricism (incl. Wittgenstein and Popper at the periphery), which manifests his (anti)philosophical heritage, partly documented in the activities of the Ernst Mach Society (“Verein Ernst Mach”). The late rediscovery and appreciation of Mach by Paul Feyerabend polarised in the same way as was the case with his provoking book *Against Method*.

1.1 Mach and His Times – An Extraordinary Intellectual Journey

Ernst Mach was an exciting man and fascinating scholar: he polarized the public and academic opinion from the *fin de siècle* to the present. He had an equal impact on philosophy, science and politics as well as on literature. In addition, he challenged the oppositions of materialism and idealism, realism and positivism, Bolshevism and Austro-Marxism, and impressionism and naturalism—and caused heated controversies about whether he was a forerunner and supporter of relativity theory or whether he rejected atomism for principled reasons? Mach’s “positivism”—he himself did not use this name for his doctrine—stands at the beginning of a long dispute that has been going on since the turn of the century around 1900: from the alleged rivalry between Mach and Boltzmann, the dispute between Mach and Planck, and the frontal attack by Lenin and his comrades, via the differences between the Vienna Circle and the Frankfurt School in the inter-war period, up to the “positivism dispute” in German sociology in the 1960s. Alongside these public confrontations and their literary variations suggesting an eternal—and suspiciously ideological—controversy, Mach’s work has enjoyed a quiet renaissance in the sciences: His works in the fields of philosophy, physics, and methodology—on concepts of measurement, the “Mach Principle”, the “Mach wave”, the “Mach number”, “Mach band”, or his “principle of economy”—opened up perspectives which still prove fruitful. In psychology Mach has been (re)discovered as a forerunner of gestalt theory, in the philosophy of science as one of the most original theorists because of his historical-critical method, and finally, as an intellectual precursor in present-day “evolutionary epistemology” (“historical epistemology”, or “history and philosophy of science”).

Mach appears to be relevant today at least for two reasons: first, as the central figure of intellectual life at the turn of the century, as reflected in his extensive correspondence, and second, as an experimental and theoretical physicist, a physiologist and psychologist of sensation, a philosopher and historian of science, and, last but not least, as an educationalist and an author of textbooks and curricula. His attempt to create a historical-social and evolutionary foundation for science corresponds to his social reform views and his political practice. He succeeded in

conquering mechanical materialism and metaphysical system philosophy while the natural sciences were in the midst of a crisis, and in formulating his doctrine of the empirical unity of physics, physiology, and psychology within the framework of a monistic scientific world-view as follows (Mach 1872/1911, 91):

Now, the problem of science can be split into three parts: 1. The determination of the connexion of presentations. This is psychology. 2. The discovery of laws of the connexion of sensations (perceptions). This is physics. 3. The clear establishment of the laws of the connexion of sensations and presentations. This is psychophysics.

Elsewhere Mach programmatically described the task of scientific cognition as the adaptation of thoughts to facts and to each other (Mach 1976, 120 ff.). The main epistemological and methodological problems initiated by the “second scientific revolution” were to be solved by means of unconventional ideas: the theory of elements, the principle of economy, and the historico-critical method on an evolutionary basis were central and at the same time controversial components of his Enlightenment conception of science. Just how much resistance Mach’s innovation encountered in the scientific community is shown not only by the dispute between him and Boltzmann and between their respective followers, or by his controversial correspondence with the scientific avant-garde of the time, but also by his own pessimism concerning the impact of his work (Mach 1883, XVI):

At the end of the last century my disquisitions on mechanics fared well as a rule; it may have been felt that the empirico-critical side of this science was the most neglected. But now the Kantian traditions gained power once more, and again we have the demand for an a priori foundation of mechanics. (cited from Mach 1989, xxvii)

The past and the present reception of Mach’s ideas with its emotional and polemical overtones illustrate the explosive potential of an interdisciplinary scientific world view with a claim to the humanization of science and society. Mach himself lived up to this proposed ideal as a promoter of general education and school reform.

What was Mach’s intellectual development leading up to his monistic world view and interdisciplinary methodology? Which role played philosophy in this regard?

Already at the age of 15 (!) Mach had read Kant’s *Prolegomena*, which resulted in a lifelong divergence from metaphysics and idealistic philosophy. He himself reports in his autobiographical manuscripts on this key experience as follows (Mach 1913, cited after Blackmore 1992, 22 f.):

The fifteen year-old youth eagerly gobbled down this clear and relatively uncomplicated work. It made a powerful impression upon him, destroyed the young man’s naive realism, stimulated an interest in epistemology, and with the help of Kant the metaphysician annihilated all tendency toward metaphysics within himself. In equal fashion, the book stimulated my thinking about scientific and psychological matters. I soon detached myself from Kant’s critical idealism. I recognized even as a boy that the thing-in-itself was a useless, metaphysical fabrication, a superfluous metaphysical illusion. I soon turned to the Berkeleyan ideas which had been latent in Kant and gradually came to a critical empiricism. If I could not remain loyal to Kant’s thoughts, I remained thankful to him for the manner in which he had stimulated me. Kant also helped my historical-critical treatment of mechanics possible. From the same spring came the Wärmelehre, the initial stages of the Optik, and so forth.

At the age of 17 Mach took his school-leaving certificate at the Kremsier grammar school and enrolled in mathematics and physics with von Ettinghausen, Grailich, and Petzval at the University of Vienna, where the ambitious student complained of shortcomings in the natural sciences. For this reason he had to undertake autodidactic studies, and he achieved his first experimental success with the construction of an apparatus proving the existence of the famous Doppler effect—an acoustic phenomenon, which was doubted at the time.

In January 1860, after 5 years of study, Mach obtained his Doctor of Philosophy with the dissertation *Über elektrische Entladung und Induktion* (On Electrical Discharge and Induction). The living situation of the young doctor was so miserable that he had to support himself by giving private lessons to school pupils—yet nonetheless in 1861 Mach was able to qualify as a *Privatdozent* for physics. He gave private lectures about Fechner's psychophysics and Helmholtz's doctrine of sound sensations. Contact with the physiologists Ernst Brücke and Carl Ludwig aroused Mach's interest in the physiology of sensation, and this encouraged him, as he later recalled, to carry out also epistemological investigations. The connections between physics, physiology, and psychophysics are one of the most characteristic features of Mach's "neutral monism". In this period as a *Privatdozent* he became acquainted with his lifelong friend, the writer, engineer, and social reformer Josef Popper-Lynkeus (1838–1921), with whom he shared the closest intellectual rapport (Belke 1978). Both of them supported the workers' movement and were active in the Vienna Fabian Society (Feuer 1974, 28). His early teaching work also led Mach to the

opinion that the historical presentation of material was the simplest and the most understandable. Such general conceptual connections revealed the economic motives of cognitive theory and the conception of science as part of a general phenomenon of life and development, a view which finally rounded out his biological and economic epistemology. (Blackmore 1992, 24)

His orientation towards medicine and physiology inspired the talented experimental physicist to develop the theory of the pulse wave plotter, recording instruments, and, above all, numerous works about the sense of hearing, for which he received a small financial stipend from the Vienna Academy of Sciences in 1864. This led indirectly to the investigation of the auricular labyrinth, which was subsequently developed by Josef Breuer (Hirschmüller 1978; Swoboda 1988) – and led eventually to the achievements of the Nobel laureate Robert Bárány in (1914).

The year 1864 marked the beginning of Mach's scientific rise with his appointment to the Chair of Mathematics and, from 1866 to 1867, that of physics at the „somewhat neglected“ University of Graz (Mach 1913, 415). There he lectured on differential and integral calculus, and also on analytical geometry. In Graz he became acquainted with the economist Emmanuel Hermann, who inspired his principle of economy; he also became accustomed to „describing the intellectual activity of the researcher as a commercial or economic one“ (Heller 1964, 15; Haller 1988). The chair of experimental physics in Prague, to which Mach was appointed in 1867, was an ideal position for him, and he held the chair until his departure

for Vienna in 1895. There Mach laid the foundation for his international reputation. Mach wrote in his own words: (cited after Blackmore (ed.) 1992, 25):

I had thought out my epistemology early, but it ripened late; also, the order of presenting my lectures ripened slowly; the best manner of carrying out experiments, which I first had to learn myself, fell into place relatively quickly through working in common with the students, above all by means of acoustic investigations, which because of similarities to work carried out during my physiological period were more easily and readily learned. Many experiments conducted in this way were published under the auspices of the Vienna Academy, but most of them would appear under the names of my assistants.

As Dean of the Faculty of Philosophy in 1872/73 and Rector of the University of Prague in 1879–80, Mach got caught up in the emerging conflict of nationalities, which reached its peak (in 1882/83) with the division of the university into a German and a Czech University. Mach himself—an opponent of every kind of nationalism—objected in vain to this division, instead advocating the creation of a second Czech university (Heller 1964, 18 f.; Hoffmann 1991). In his first year in Prague he published a short report entitled „Über die Definition der Masse“ (On the Definition of Mass), and among the most important publications from Mach’s Prague period are *Optisch-akustische Empfindungen* (Optical-Acoustic Sensations) (1872) and *Grundlinien der Lehre von den Bewegungsempfindungen* (Outlines of the Doctrine of Sensations of Movement) (1875), as well as diverse stroboscopic investigations. At the same time Mach—due to an illness—resumed his historical-critical studies, which culminated in the publication of a programmatic study entitled *Die Geschichte und die Wurzel des Satzes der Erhaltung der Arbeit* (1872) (*The History and Root of the Principle of the Conservation of Energy*), in which he rejected any form of a metaphysical and one-sided mechanical conception of physics as well as the aprioristic, synthetic categories of absolute movement, absolute space, and absolute time as superfluous notions of substance. In these fundamental works the principle of thought economy was formulated and the groundwork laid for Mach’s subsequent major works *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt* (1883) (*The Science of Mechanics*) and *Die Prinzipien der Wärmelehre. Historisch-kritisch entwickelt* (1896) (*The Principles of the Theory of Heat: A Historical and Critical Treatment*). His *Mechanics* emphasized the historical analysis of knowledge as *the* method for understanding mechanics. By drawing on the works of Gustav R. Kirchhoff and Hermann Helmholtz, he elaborated his idea of „*the nature of science as one of an Economy of Thought*“ (Mach 1888/1989, xxiii) which underlay his anti-essentialist methodology based on conception analysis and led to a fallibilistic epistemology (anticipating Karl Popper’s falsificationalism) programmatically detailed in Mach’s *Erkenntnis und Irrtum* (*Knowledge and Error*) (Mach 1989, 586 f.):

The function of science, as we take it, is to replace experience. Thus, on the one hand, science must remain in the province of experience, but, on the other, must hasten beyond it, constantly expecting confirmation, constantly expecting the reverse. Where neither confirmation nor refutation is possible, science is not concerned. Science acts and acts only in the domain of uncompleted experience.

To promote these aims, Mach combined the criteria of scientific probity (Rechtschaffenheit), simplicity, and beauty with the principle of the economy of research. The historical-critical method as well as the biological-psychological model of explanation allowed Mach to describe mechanics from the „collected experiences of handicraft by an intellectual process of refinement“ and produce the causal connection between history, the everyday world, and science in a longitudinal section (ibid., 485; also Thiele 1969; cited from 1989, 612). In his *Theory of Heat*, Mach explicated the basic concepts of temperature and heat capacity from a historical-genetic perspective and explained the principles of energy conservation and of entropy (Mach 1986). From as early as the 1870s he had been working sporadically on a history of optics, the publication of which he had repeatedly postponed, until he finally decided to have it published posthumously by his son Ludwig; it eventually appeared in 1921 with Ludwig’s controversial preface against the theory of relativity. Ten years earlier his main work on epistemology, *Beiträge zur Analyse der Empfindungen* (1886; English 1959), had been published. It contained a critique of the Kantian “thing in itself” and the “unchanging ego” which was not only a rejection of the Christian dogma of personal immortality, but also allowed Mach to acknowledge an affinity to Buddhism.

On his basic concern in both his *Analysis of Sensations* and in his more mature *Knowledge and Error* (1905) Mach formulated the thesis that

... the entire internal life of people breaks down into elements and that everything human beings experience or pass through represents the dependence of two groups of these elements, external experience, that is, the physical or perceptual life, and internal experience, that is, the psychical as conceptual life. The first kind of existence is no arbitrary creation of our fantasy as I believe that I have already sufficiently said. Therefore, there was no need for some physicists to have to misunderstand me, still less for certain philosophers to have helped guide them to that conception. I have also spoken about a monism of physical and psychical events. There are not two different worlds, and that is not what the issue is about. I am only concerned with examining the kind of dependence between the two. I am also required by this monism, however, to clarify the unity of human experience in light of the distinction between my ego and those of other people. (ibid., 416; cited from Blackmore ed.), 1992, 26)

This pointed piece of self-presentation refers to psycho-physical monism, which has by now become classical, as well as a determined anti-idealism (with reference to Lenin, Planck, and others) and the natural, uniform notion of the world based on a pragmatist and an empiricist concept of knowledge (with reference to the criticism of his friend Wilhelm Jerusalem).

Mach explained the economic and biological theory of knowledge simply, and with typical modesty he also admitted the fundamental incompleteness of his theory as a basis for discussion, which he would present again in his *Popular-Scientific Lectures* (1895)/*Populärwissenschaftliche Vorlesungen* (1896)—a collection documenting the family resemblance with American pragmatism (from Peirce, James to Dewey).

In his *Analyse der Empfindungen* (1886) (*Analysis of Sensations*) Mach dealt with the central theme of a uniform, empirical foundation of science consisting of the integration of philosophy, physics, psychology (of sensation), and biology.

The anti-metaphysical doctrine of elements was elaborated under the influence of Berkeley and Hume and the psychophysics of Fechner and constituted his neutral monism (Mach 1918, VI; cited from Mach 1959, xl f.):

The opinion, which is gradually coming to the front, that science ought to be confined to the compendious representation of the actual, necessarily involves as a consequence the elimination of all superfluous assumptions which cannot be controlled by experience, and, above all, of all assumptions that are metaphysical in Kant's sense. If this point of view is kept firmly in mind in that wide field of investigation which includes the physical and the psychical, we obtain, as our first and most obvious step, the conception of the sensations as the common elements of all possible physical and psychical experiences, which merely consist in the different kinds of ways in which these elements are combined, or in their dependence of one another. A whole series of troublesome pseudo-problems at once disappears. The aim of this book is not to put forward any system of philosophy, or any comprehensive theory of the universe. It is only the consequences of this single step, to which any number of others may be attached, that are examined here. An attempt is made, not to solve all problems, but to reach an epistemological position which shall prepare the way for the co-operation of special departments of research, that are widely removed from one another, in the solution of important problems of detail.

Here, Mach's antipathy to metaphysical system philosophy is documented once again and the fundamental incompleteness of the scientific world view once more emphasized.

In 1895 Mach was appointed to the chair of „philosophy, in particular the history and theory of the inductive sciences,“ which had been specially created for him at the University of Vienna (Mayerhöfer 1967, 12–25; Blackmore 1972, 145–63). This return to Vienna was made possible during the short period of a coalition of the ‘united left’ (the German Liberals, United Progress Party, and the German Conservatives and the cultural minister Madeyski-Poraj) and with the help of Theodor and Heinrich Gomperz at the university level, despite „the most vehement agitation from the clerical side“ (Mach to Meinong, in Kindinger 1965). However, Mach's teaching and research in Vienna was greatly impaired in 1898, when the 61 year-old man suffered a stroke that severely paralyzed the right side of his body, although it left him in full possession of his mental faculties. In 1901, after several interruptions, he finally had to submit his application for retirement (Blackmore and Hentschel 1985, 29 f.).

Having been awarded the title of ‘Hofrat’ (a title awarded to long-standing, meritorious civil servants) in 1896, Mach was appointed as a life-long member of the upper chamber (Herrenhaus) of the Austrian parliament upon retirement, although—in accordance with his views—he did not accept the title of nobility such an appointment usually entailed. Despite his poor state of health he had himself taken to parliament in an ambulance in 1901 to vote on the nine-hour working day—a process he repeated for the vote on the universal franchise in 1907.

Mach resumed his attitude in his last major work, *Erkenntnis und Irrtum. Skizzen zur Psychologie der Forschung* (1905) (*Knowledge and Error*), in which he supplied a summary of his teaching and research activities in Vienna in particular, as well as of all of his previous work. Natural science was explained from a biological, psychological, and social point of view and the precedence of practical research over

theoretical abstraction, (as dominant in philosophy following Mach) was emphasized. This rejection of metaphysical system philosophy alone allowed Mach to state that he was „not a philosopher, but only a scientist, “ who “aimed not at introducing a new philosophy into science, but at removing an old and stale philosophy from science . . . “ (Mach 1917, VI, cited from Mach 1976, XXXII; Hiebert 1976).

Mach also provided a survey of the current state of research in psychophysics and the psychology of thought and perception. His treatment of the body-mind problem as a pseudo-problem and the hypothetical character of our knowledge points the way for the future of the Vienna Circle, when he concludes that “. . . the same mental functions, operating under the same rules, in one case led to knowledge and in another to error; from the latter, only repeated and exhaustive examination can protect us.” (Mach 1917, 125; cited from Mach 1976, 90). This is obviously directed against a naive inductivism.

Together with the principles of empiricism and nominalism, of the economy of thought and enquiry, and, finally, with a concept of philosophy oriented towards critique of language, the intellectual basis for the development of logical empiricism was thus prepared.

After his early retirement, Mach was practically confined to his room in Gersthof in Vienna’s 18th district, where he was still able to engage in intellectual work with the aid of a typewriter specially adapted to his disability, even though he was no longer conversant with the latest experimental research in physics. This was why Mach devoted himself primarily to historical and social or anthropological studies in the last years of his life. In his last small book *Kultur und Mechanik (Culture and Mechanics)* (1915) he reconstructed the development of mechanics and science since pre-historical times from a general socioeconomic perspective.

In May 1913 Mach moved to live with his eldest son Ludwig near Munich. He died amidst the turmoil of World War I on February 19, 1916, protected by his son. At the wish of the deceased, only the closest circle of friends and relatives were present at the cremation ceremony. This reminds us of the unity of life and work that Mach maintained until his death, about which he had stated generally but radically in the *Analysis of Sensations* (Mach 1900, 17, cited from Mach 1959, 24 f.):

The ego must be given up. It is partly the perception of this fact, partly the fear of it, that has given rise to the many extravagances of pessimism and optimism, and to numerous religious, ascetic, and philosophical absurdities. In the long run we shall not be able to close our eyes to this simple truth, which is the immediate outcome of psychological analysis. We shall then no longer place so high a value upon the ego, which even during the individual life greatly changes, and which, in sleep or during absorption in some idea, just in our very happiest moments, may be partially or wholly absent. We shall then be willing to renounce individual immortality, and not place more value upon the subsidiary elements than upon the principal ones. In this way we shall arrive at a freer and more enlightened view of life, which will preclude the disregard of other egos and the over-estimation of our own

Now, let me turn to the complex and critical relation of Mach to philosophy:

1.2 Mach and Philosophy

Ernst Mach’s oeuvre continues to exert a remarkable interdisciplinary influence, covering philosophy, the natural sciences, and the social sciences, as well as on literature and art (Thiele 1963). From a chronological point of view his influence occurred in waves, from a geographical point of view it varied in intensity and it concentrated on specific subjects. In Austria-Hungary he was able to impress a large number of the representatives of the so called “scientific philosophy”—among them Wilhelm Jerusalem, Heinrich Gomperz, and Adolf Stöhr. For religious and political reasons the reception of Kant and Hegel in Austria was rather limited compared to that of the realistic and phenomenological traditions (Bolzano, Zimmermann, and the Brentano School).¹ Nevertheless, some exceptions served to prove these underlying trends: on the one hand, a distinct Kantian tradition in Austria right up until Robert Reininger, on the other hand an acceptance of Machian positivism in the German Empire by both researchers and philosophers in the natural sciences, for example Josef Petzoldt, Wilhelm Ostwald, Wilhelm Schuppe, Ernst Haeckel (the founder of the German Monist Society), and even some of the Neo-Kantians (Hans Vaihinger, Alois Riehl). And Mach himself – after his encounter with Kant’s *Prolegomena* – returned to Kant with the study of the German philosopher Eduard Beneke (1798–1854).²

Furthermore, his dealing with methodology between induction and deduction is an allusion to and variation of the famous response of Kant to Hume. But afterwards, in *The Science of Mechanics*, he rejected the absolute notions of space and time, again repeated in *Knowledge and Error* (1905). Most recently, from an epistemological point of view, there is a discussion, whether Mach can be also characterized in the frame of a realist empiricism (as an alternative to phenomenalism), as was proposed by Erik Banks in his book *The Realist Empiricism of Mach, James, and Russell. Neutral Monism Reconceived* (2014).

On the institutional level, there existed the “German Society for Positivist Philosophy”, the founding manifesto of which was signed in 1911 by Albert Einstein, David Hilbert, and Sigmund Freud among many other scholars like Wilhelm Jerusalem, Felix Klein, Wilhelm Schuppe.³ In the Weimar Republic this scientific tradition continued in the Berlin Society for Empirical (Scientific) Philosophy, while in Austria during the First Republic Mach’s work was widely received in the Vienna Circle and in the Ernst Mach Society (Verein Ernst Mach), which—as the name suggests—was the Circle’s popular platform. These two related tendencies were nevertheless rather atypical, marginal traces of his reception in the Austrian and German philosophical landscape as a whole. Comparatively, Mach’s

¹Topitsch 1949; Sauer 1982; Haller 1986.

²Siemsen 2015.

³Lübbe 1963; Blackmore 1972, 190 ff.; Holton 1993.

acceptance in the academic field was far smaller than it was in Vienna's cultural movement. (Glaser 1981).

Whereas almost all members of the Vienna Circle—as well as Boltzmann, Einstein, Russell, and Wittgenstein—drew on Mach to varying degrees (which by no means excluded taking a critical approach), it was the interdisciplinary concept of the anti-metaphysical scientific world view, above all, which was promoted in the Ernst Mach Society. Already the proto-Circle of the Vienna Circle before World War I, with Philipp Frank, Otto Neurath, and Hans Hahn, (and Richard von Mises in parallel) had begun to discuss with Mach the (un)scientific nature of philosophy, the possibility of a synthesis of empiricism and conventionalism, in particular, to bring together Mach with Duhem, Poincaré, Brentano, Meinong, Husserl, Helmholtz, and Freud.⁴ Later the critique of the older positivism in all its different variations was continued by Rudolf Carnap, Karl Menger, Moritz Schlick, Herbert Feigl, Bela Juhos, and Viktor Kraft, and, above all, by Philipp Frank and Richard von Mises. In contrast, Karl Popper's *Logic of Scientific Discovery* (*Logik der Forschung* (1934)) develops an objectivism and realism which corresponded rather to Lenin's anti-Machian concerns. In his intellectual biography, Popper presented himself as continuing the Boltzmann-Einstein tradition in a way which precluded any positive reception of Mach and even led him to become the self-appointed destroyer of "logical positivism" (Müller et al. 1986).

But let's go to single members of the Vienna Circle of Logical Empiricism in more detail:

By incorporating quantum theory and relativity theory, the physicist Philipp Frank was able to conceive of Mach's methodology as a keystone of logical empiricism, supplementing it with formal logic and axiomatics (Frank 1949b). With these instruments French conventionalism was modernized and developed together with the Machian empiricism into the scientific philosophy (Logical Empiricism) of the Vienna Circle. Thus a methodological holism, propagated by Duhem and Neurath, was present even before World War I, and would later be rediscovered by Quine (Haller 1982).

Otto Neurath advocated a coherentist standpoint and investigated the holistic and sociological dynamics of theories, which later led to the decisive criteria of empirical unified science, the 'encyclopedia.' His two letters to Mach dating from 1914 illustrate Mach's significance for relativity theory and his influence on Neurath's own work, whether in the history of science, the theory of value, or the theory of political economy (Thiele 1978, 99–101). The great esteem that Mach enjoyed could not be diminished by the fact that his skepticism towards atomic theory and his preference of the physiology of sensation as a foundation for physics were criticized later on in the Vienna Circle's manifesto. Neurath shared Mach's reservations towards an overemphasis on formalization and meta-theoretical orientation in empirical science.

The mathematician Hans Hahn was most responsible for the adoption of formal logic (and Wittgenstein's *Tractatus*) by the Vienna Circle, at the same

⁴Frank 1949a; Haller 1986a.

time vehemently advocating Mach’s anti-metaphysical principle of economy—in the form of Occam’s razor (Hahn 1930). The mathematician and logician Karl Menger discussed the possibility of a positivist geometry and the productivity of the mathematical concept of function in its application to science and provided the sixth English edition of Mach’s *Mechanics* with a historico-critical introduction, in which he pointed out the topicality of Mach’s history and theory of science (Menger 1979, 107–25; 1960, V–XXI).

The most effective, systematic reworking of these innovations in the theory of science and epistemology was undoubtedly supplied by Rudolf Carnap in his two books *Der logische Aufbau der Welt* (1928) and *Scheinprobleme der Philosophie. Das Fremdpsychische und der Realismustreit* (1928) (*The Logical Structure of the World. Pseudoproblems of Philosophy* (1967a)). These central writings from the early Vienna Circle represent an attempt to create a hierarchical system of the constitution of scientific concepts on an empirical basis, namely proceeding by means of a phenomenalist language from the Machian ‘elements’ as building blocks with the aid of type theory. Its basic concepts were defined by the logical relationship between such elements (Carnap 1963, 1979, XI). However, in the 1930s a physicalist language was instead proposed by Carnap and Neurath to serve as the medium of a unified science—a development which cannot be discussed further here (Uebel 1992).

Moritz Schlick, a trained physicist, dealt with Mach in his first major work *Allgemeine Erkenntnislehre* (1918) (*General Theory of Knowledge* (1974)), in which he criticized “immanent positivism” from the point of view of his critical realism. After 1922, however, he changed his position, mainly as a result of the influence of Ludwig Wittgenstein, to that of an, to use his own terminology, „consistent empiricism.“ (konsequenter Empirismus). Einstein, among others, was skeptical of this “linguistic change” in their correspondence on the matter (Hentschel 1986).

Nor was Schlick’s reversal accepted by his pupil Herbert Feigl, who felt himself committed rather to a “critical realism”—following the same path as Kraft (Kraft 1912) and Karl Popper. Nevertheless, Feigl still considered Mach and Ostwald the idols of his youth, at least until he became enthusiastic about Boltzmann and Planck and their atomist views (Feigl 1981, 1969, 57–94).

This aspect only played a secondary role in the engineer and (applied) mathematician Richard von Mises’ view of Mach. He wrote overall surveys including *Ernst Mach und die empiristische Wissenschaftsauffassung* (*Ernst Mach and the Empirical View of Science*) (1938) and *Positivism. A Study in Human Understanding* (1968; *Kleines Lehrbuch des Positivismus* (1939)). In the former, von Mises provides a philosophical and historical excursus from Hume to Mach, whom he describes as „the most influential and, for our time, the most characteristic enlightenment philosopher of recent generations“ (von Mises 1963–64, 499). In his remarks in *Positivism*, von Mises described himself as a student of Mach, although he took a critical view of the problem of language (ibid., 524–29).

The philosopher, sociologist and historian of science Edgar Zilsel (1891–1944) played a special role within and outside the Schlick-circle, but also with strong references to Mach.

We can complete this short overview of Mach's influence in philosophy (of science) with his long-standing friend as well as his intellectual counterpart Josef Popper-Lynkeus (1838–1921). He was an engineer, writer, philosopher, and social reformer, and became the subject of much controversy for the socio-liberal middle-class at the fin de siècle.⁵

In his posthumous published fragments he draws on his (language critical) theory of knowledge (1932–33, 301–24):

If one says, 'The world appears to me like this', and not, 'The world is like this', that already contains a hypothesis. Philosophy must not go beyond what is experienced. 'The rest is silence.' Thereby setting limits to skepticism. 'Learning to tolerate incomplete world-views', is how Mach once explained it to me very fittingly. One could also put it like this: Shut up and go on-living.

This statement provides some biographical, historical, and theoretical plausibility to the joint mention of Mach and Popper-Lynkeus in the Vienna Circle's Manifesto. And perhaps it is no accident that the two friends' busts can be found together in the park of Vienna's City Hall and not in the hall of fame at the University of Vienna, where the absence of Ernst Mach and Moritz Schlick is somewhat astounding.

Finally, it is worth mentioning that Paul Feyerabend, one of the most vehement critics of critical rationalism and of the analytical philosophy, referred to Ernst Mach's historical-critical methodology in order to favor the pragmatic-historical against the abstract-theoretical tradition in the philosophy of science (Feyerabend 1978, 51–60, 1981). This perspective seems to be an original attempt to modernize Mach's theory of science as a critique of current ideas and to overcome classic antagonisms such as philosophy *and* science, positivism *and* realism, and idealism *and* materialism by means of a historicizing approach (Feyerabend 1978, 202):

While Mach's criticism was part of a reform of science that combined criticism with new results the criticism of the positivists and of their anxious foes, the critical rationalists proceeded from some frozen ingredients of the sciences (or modifications thereof) that could no longer be reached by the process of research. Mach's criticism was dialectical and fruitful, the criticism of the philosophers was dogmatic and without fruit.

Based on this explanatory approach, several variations of 'positivism' would vanish as conceptually determined misunderstandings, like those which arose in the controversy between 'positivists' and 'realists', namely between Mach and Boltzmann, Mach and Planck, and Schlick and Planck (Stadler 1983).

However, Ernst Mach's influence extended far beyond the field of pure philosophy, especially affecting the critique of language and the literature of his time. This does not come as a surprise, perhaps, considering Mach's fondness for the aphorist Georg Christoph Lichtenberg. Unfortunately, precisely Mach's ideas on language seem to have been left out of the research to date.⁶ In this respect the correspondence between Mach and the young journalist and linguistic philosopher Fritz Mauthner

⁵Popper-Lynkeus 1917; Neurath 1918; Frank 1918; Schlick 1926; R. von Mises 1918, 1931; Loewy 1932; Frei 1971; Belke 1978; Hellin and Plank 1979.

⁶As positive exceptions, see Diersch 1977; Wunberg (ed.) 1981.

provides a unique chronicle of Mach’s non-academic reception, exemplified in Mauthner’s principal work *Beiträge zu einer Kritik der Sprache* (Contributions to a Critique of Language) (1901), which presents an anti-metaphysical and nominalistic critique of language.⁷

Mach’s influence in Austria extends at least as far as Ludwig Wittgenstein’s *Tractatus logico-philosophicus* and is directly related to Mauthner’s position—even if Wittgenstein intentionally maintains his distance towards from latter’s psychological and historical method: „*All philosophy is critique of language. (Though not in Mauthner’s sense)*“ (*Tractatus* 4.0031). This topos shows the intellectual affinity with thinkers such as Karl Kraus and Adolf Loos—both of whom were also great admirers of Lichtenberg, and who worked on a complex of problems including ethics, language, and society in various areas (Janik and Toulmin 1973, 120–32). Last but not least, there is also Wittgenstein’s study of Mach, which can be discerned in some fragments of the *Tractatus* and the *Philosophical Remarks*.⁸ The impossibility of a general statement concerning the world as a whole, neutral monism on a physical basis, the instrumentalist understanding of language, the genesis of language as a consequence of following rules, and the idea of thought experiments all represent convergent themes.

There can be no doubt about the extent to which Ernst Mach, together with Ludwig Boltzmann, has influenced the current generation of physicists⁹—a fact confirmed by the frequently over-emphasized notion of the gigantomachy between the two thinkers. The communication between “positivism” and “realism” ran through all camps both in Austria and abroad: from Einstein to the Vienna Circle, from Friedrich Adler to Max Planck, and to the Monists and the Peace Movement in the Viennese late-Enlightenment, prior to the formation of the Ernst Mach Society. It is found in the extensive correspondence between the leading scientists of the time, especially in connection with quantum theory, and it has continued to the present day, with the relationship between Mach and Boltzmann and their influence on Einstein still being the subject of contemporary research. What is undisputed is the skepticism with which Mach, as a result of his empirical epistemology, viewed an atomism that seeks to be anything more than a hypothetical model for interpreting “reality”. Towards the end of his life, Mach’s attitude towards relativity theory appears to have been an open one, as the authenticity of the preface to the *Optics* can be questioned (Wolters 1987). After 1900, as a result of their correspondence on this matter, there was a considerable rapprochement in the views of Boltzmann and Mach. The correspondence between them is evidence of an intensive and, in the last analysis, convergent discussion, although one that excluded atomism. It reflects the untenable view that Boltzmann’s rivalry with Mach was one of the main reasons

⁷Weiler 1970; Kühn 1975; Mauthner 1986. Cf. the correspondence between Mauthner and Mach in Haller and Stadler (ed.) 1988, 229–43; Leinfellner and Schleichert (ed.) 1995.

⁸Blackmore 1972, 185; Hayek 1966, 42; Feyerabend 1955; Gargani 1980; Visser 1983.

⁹Cf. the corresponding texts in Cohen and Seeger (ed.) 1970. Also see Haller and Stadler (ed.) 1988; Hoffmann and Laitko (ed.) 1991; Blackmore (ed.) 1992; Blackmore (ed.) 1995.

for the former's suicide in Duino near Trieste in 1906. Despite undeniable epistemological differences, they had a common basis with regard to anti-metaphysical philosophy, Darwinism, and conventionalist methodology, against the background of an enlightened social-liberalism. Undeniable as well is Mach's significance as a precursor of relativity theory, as Albert Einstein himself testified, particularly in his criticism of Newton's classical mechanics, which inspired Einstein to "Mach's principle". It was not until the 1920s that Einstein distanced himself philosophically from Mach's 'positivism' and began to approach "realism" from the Planckian point of view (Feyerabend 1988). Many physicists, including the representatives of the "Copenhagen interpretation" of quantum theory, regarded Machian epistemology as an—ontologically neutral—methodical phenomenalism (just as Carnap and Schlick did) and placed much importance on the fruitfulness of his experimental physical and historical work, leaving any epistemological controversies to one side (Faye 1991). An additional psycho-social explanation of the fascination exerted by Mach upon a whole generation of physicists may lie in the cognitive and emotional identification of a group of young revolutionary scientists with Mach and Popper-Lynkeus as the destroyers of classical mechanics: in their eyes, there was an analogy between the social and the scientific revolution and between ethical and physical relativism (Feuer 1974, 42 ff.).

It seems, what Albert Einstein wrote in his obituary is still valid for the evaluation of Mach's work and influence today:

The fact is that Mach through his historical and critical writings in which he followed the development of the individual sciences with so much love and traced historical details into the inner sanctum of the brain of path breaking scientists has had a great influence on our generation of natural scientists. I even believe that the people who consider themselves opponents of Mach, scarcely know how much of Mach's way of thinking they have absorbed, so to say, with their mother's milk. . . . I at least know that I have been directly or indirectly aided by Hume and Mach. (cited. from Blackmore (ed.) 1992, 154 ff.)

References

- Stadler, Friedrich. 1982. *Vom Positivismus zur „Wissenschaftlichen Weltauffassung“. Am Beispiel der Wirkungsgeschichte von Ernst Mach in Österreich von 1895 bis 1934*. Wien/München: Löcker.
- Haller, Rudolf and Friedrich Stadler (Hrsg.) 1988. *Ernst Mach – Werk und Wirkung*. Wien: Hölder-Pichler-Tempsky.
- Stadler, Friedrich. 1988. „Ernst Mach – Zu Leben, Werk und Wirkung“, in: Haller/Stadler, 11–57.
- Stadler, Friedrich. 2015. *The Vienna Circle. Studies in the Origins, Development, and Influence of Logical Empiricism*. Cham: Springer. German edition: *Der Wiener Kreis. Ursprung, Entwicklung und Wirkung des Logischen Empirismus im Kontext*. Cham: Springer 2015.
- Stadler, Friedrich. 2017. „Ernst Mach and Pragmatism – The Case of Mach's *Popular Scientific Lectures* (1895)“. In: Sami Pihlstrom, Friedrich Stadler, and Niels Weidtmann (Eds.), *Logical Empiricism and Pragmatism*. Cham: Springer, 3–14.
- Stadler, Friedrich. 2018. “George Sarton, Ernst Mach, and the Unity of Science Movement”, in: *Sartoniana*. Ed. by Robert Rubens and Maarten Van Dyck. Vol.31/2018. Ghent: Ghent University Press, 63–122.

The main books of Mach in German are published with introductions in the *Ernst Mach Studienausgabe* (Berlin: xenomoi), ed. by Friedrich Stadler, together with Michael Heidelberger, Dieter Hoffmann, Elisabeth Nemeth, Wolfgang Reiter, Jürgen Renn, Gereon Wolters:

- Ernst Mach, *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen* (1886). Ed. by Gereon Wolters (2008).
 Ernst Mach, *Erkenntnis und Irrtum* (1905). Ed. by Elisabeth Nemeth und Friedrich Stadler (2011).
 Ernst Mach, *Die Mechanik in ihrer Entwicklung. Historisch-kritisch dargestellt* (1883). Ed. by Gereon Wolters and Giora Hon (2012).
 Ernst Mach, *Populärwissenschaftliche Vorlesungen* (1896). Ed. by Elisabeth Nemeth and Friedrich Stadler (2014).
 Ernst Mach, *Die Prinzipien der Wärmelehre* (1896). Ed. by Michael Heidelberger and Wolfgang Reiter (2016).
 Ernst Mach, *Die Prinzipien der physikalischen Optik* (1921). Ed. by Dieter Hoffmann (2019).

References

- Friedrich, Adler. 1918. *Ernst Machs Überwindung des mechanischen Materialismus*. Wien.
 Erik Banks, *The Realist Empiricism of Mach, James, and Russell. Neutral Monism Reconceived*. Cambridge: University Press 2014.
 Ingrid Belke, *Die sozialreformerischen Ideen von Josef Popper-Lynkeus (1838–1921) im Zusammenhang mit allgemeinen Reformbestrebungen des Wiener Bürgertums um die Jahrhundertwende*. Mohr: Tübingen 1978
 John Blackmore, *Ernst Mach. His Work, Life, and Influence*. Univ. of California Press: Berkeley-Los Angeles-New York 1972.
 John Blackmore, „Three Autobiographical Manuscripts by Ernst Mach“, in: *Annals of Science* 35, 1978, pp.401–418.
 John Blackmore (ed.), *Ernst Mach – A Deeper Look. Documents and New Perspectives*. Kluwer Academic Publ.: Dordrecht-Boston-London 1992.
 John Blackmore (ed.), *Ludwig Boltzmann: His Later Life and Philosophy, 1900–1906*. 2 Vols. Kluwer Academic Publ.: London-Dordrecht-Boston 1995.
 John Blackmore und Klaus Hentschel (Hrsg.), *Ernst Mach als Außenseiter*. Braumüller: Wien 1985.
 Franz Brentano, *Über Ernst Machs “Erkenntnis und Irrtum”*. Edited by Roderick Chisholm und Johann C. Marek. Rodopi: Amsterdam 1988.
 Max Brod, *Streitbares Leben. Autobiographie 1884–1968*. Insel-Verlag, Frankfurt/M. 1979.
 Karl Bühler, *Die Krise der Psychologie*. Gustav Fischer: Jena 1927.
 Rudolf Carnap, “Intellectual Autobiography”, in: *The Philosophy of Rudolf Carnap*. Ed. by P.A. Schilpp, 1963, pp.1–84.
 Rudolf Carnap, *Der logische Aufbau der Welt*. Ullstein: Frankfurt/M.-Wien-Berlin 1979.
 Roderick Chisholm, *Brentano und Meinong*. Rodopi: Amsterdam 1982.
 Robert S. Cohen and R.J. Seeger (eds.), *Ernst Mach. Physicist and Philosopher*. Reidel: Dordrecht 1970.
 Manfred Diersch, *Empiriekritizismus und Impressionismus. Über Beziehungen zwischen Philosophie, Ästhetik und Literatur um 1900 in Wien*, Rütten & Loening: Berlin 1977.
 Reinhard Fabian (Hrsg.), *Christian von Ehrenfels. Philosophische Schriften*. Bd I–IV. Philosophia Verlag, München-Wien 1983.
 Reinhard Fabian (Hrsg.), *Christian von Ehrenfels. Leben und Werk*. Rodopi: Amsterdam 1986.
 Jan Faye, 1991. *Niels Bohr: His Heritage and Legacy*. Dordrecht-Boston-London.

- Herbert Feigl, "The Wiener Kreis in America", in: D. Fleming/B. Bailyn (eds.), *The Intellectual Migration: Europe and America, 1930–1960*. Cambridge, Mass., 1969, pp.630–673.
- Herbert Feigl, *Inquiries and Provocations. Selected Writings 1929–1974*. Ed. by Robert Cohen. Dordrecht 1981.
- Lewis S. Feuer, *Einstein and the Generations of Science*. Basic books: New York 1974.
- Paul Feyerabend, 1955. "Wittgenstein's 'Philosophical Investigations'", in: *The Philosophical Review* 64, 449–483.
- Paul Feyerabend, *Der wissenschaftstheoretische Realismus und die Autorität der Wissenschaften*. Vieweg: Braunschweig-Wiesbaden 1978.
- Paul Feyerabend, 1980. *Erkenntnis für freie Menschen*. Frankfurt/M.
- Paul Feyerabend, *Probleme des Empirismus*. Vieweg: Braunschweig-Wiesbaden 1981.
- Paul Feyerabend, 1988. „Machs Theorie der Forschung und ihre Beziehung zu Einstein“, in: Haller / Stadler (Hrsg.), *Ernst Mach - Werk und Wirkung*, 435–462.
- Philipp Frank, „Josef Popper-Lynkeus – Zu seinem achtzigsten Geburtstag“, in: *Physikalische Zeitschrift* 19, 1918 57 ff.
- Philipp Frank, *Modern Science and its Philosophy*. Harvard University Press, Cambridge 1949a.
- Philipp Frank, „Einstein, Mach, and Logical Positivism“, in: *Albert Einstein: Philosopher-Scientist*. Ed. by P.A. Schilpp, 1949b, pp.271–286.
- Bruno Frei, *Der Türmer*. Notring:Wien 1971.
- Friedrich Jodl, 1917. "Ernst Mach und seine Arbeit ‚Erkenntnis und Irrtum‘", in: Ernst Mach, *Erkenntnis und Irrtum*. 3. Auflage. Leipzig.
- Aldo Gargani, „Wittgenstein's Conception of Philosophy in Connection with the Works of Ernst Mach and Ludwig Boltzmann“, in: Rudolf Haller/Wolfgang Grassl (Hrsg.), *Sprache, Logik und Philosophie*. Hölder-Pichler-Tempsky: Wien 1980.
- Ernst Glaser, *Im Umfeld des Austromarxismus. Ein Beitrag zur Geistesgeschichte des österreichischen Sozialismus*. Europa Verlag: Wien-München-Zürich 1981.
- Hans Hahn, 1930. *Überflüssige Wesenheiten. Occams Rasiermesser*. Wien.
- Rudolf Haller, *Studien zur österreichischen Philosophie. Variationen über ein Thema*. Rodopi: Amsterdam 1979.
- Rudolf Haller, „Das Neurath-Prinzip. Grundlagen und Folgerungen“, in: Friedrich Stadler (Hrsg.), *Arbeiterbildung in der Zwischenkriegszeit. Otto Neurath – Gerd Arntz*. Wien, 1982, pp.79–87.
- Rudolf Haller, „Der erste Wiener Kreis“, in: Rudolf Haller, *Fragen zu Wittgenstein und Aufsätze zur österreichischen Philosophie*. Rodopi: Amsterdam 1986a, pp.89–107.
- Rudolf Haller, *Fragen zu Wittgenstein und Aufsätze zur österreichischen Philosophie*. Rodopi: Amsterdam 1986b.
- Rudolf Haller, „Grundzüge der Machschen Philosophie“, in: Rudolf Haller and Friedrich Stadler (Ed.), *Ernst Mach – Werk und Wirkung*. Hölder-Pichler-Tempsky, Wien 1988, pp.64–86.
- Rudolf Haller and Friedrich Stadler (Ed.), *Ernst Mach – Werk und Wirkung*. Hölder-Pichler-Tempsky, Wien 1988.
- Friedrich August von Hayek, „Diskussionsbemerkungen über Ernst Mach und das sozialwissenschaftliche Denken in Wien“, in: *Symposium aus Anlaß des 50. Todestages von Ernst Mach*. Hrsg. von W. Merzkirch. Ernst-Mach-Institut. Freiburg/Br., 1966, pp.41 ff.
- Karl Daniel Heller, *Ernst Mach. Wegbereiter der modernen Physik. Mit ausgewählten Kapiteln aus seinem Werk*. Springer: Wien-New York 1964.
- Klaus Hentschel, „Die Korrespondenz Einstein-Schlick: Zum Verhältnis der Physik zur Philosophie“, in: *Annals of Science* 43, 1986, pp.475–488.
- Frederick P. Hellin und Robert Plank, *Der Plan des Josef Popper-Lynkeus*. Vorwort Richard Coudenhove-Kalergi- Lang: Bern 1979.
- Schnädelbach, Herbert. 1983. *Philosophie in Deutschland 1831–1933*. Frankfurt/M.
- Theo Hermann, „Ganzheitspsychologie und Gestalttheorie“, in: H. Balmer (Ed.), *Geschichte der Psychologie*, Bd.II. Weinheim-Basel, 1982, pp.573–658.
- Erwin Hiebert N. 1976. „Ernst Mach's *Knowledge and Error*. Introduction“, in: Ernst Mach, *Knowledge and Error*, xi–xxx.
- Erwin Hiebert, „Introduction“, in: Mach, *Knowledge and Error*, Reidel: Dordrecht 1979, pp. i–xxx.