

CHAPTER 8

Critical Thinking Through Mach and Duhem: The Use of History

María de Paz

Abstract This chapter explores the use of history by Ernst Mach and Pierre Duhem as a method for critical thinking in the philosophy of science. To gain a novel understanding of their approach, their views are contrasted with Martin Heidegger's early analysis of time in history, as presented in "The Concept of Time in the Science of History" (1916). While Heidegger seeks to ground history in metaphysics and cultural values, thereby reinforcing the separation between natural and human sciences, Mach and Duhem employ history to dissolve such boundaries. For them, history prevents science from becoming dogmatic, reveals its dynamic and evolving character, and enables the scientist to view the present from perspectives other than their own. It opens possibilities for evaluating the current state of scientific disciplines and provides an essential tool for the intellectual formation of scientists. By confronting Heidegger's metaphysical conception of history with Mach's and Duhem's empirically grounded historical practice, this paper argues that their approach transforms history into a critical instrument within science itself—one that unites rather than divides philosophy, science, and culture, and reveals the inseparable historical nature of scientific knowledge.

Keywords Mach · Duhem · History · Heidegger · Historical-critical method · Time

M. de Paz (✉)
Universidad de Sevilla, Sevilla, Spain
e-mail: mdepaz3@us.es

© The Author(s) 2027

J. Cordovil et al. (eds.), *Portuguese Studies in Philosophy of Science*, Boston Studies in the Philosophy and History of Science 352,
https://doi.org/10.1007/978-3-032-41569-1_8

8.1 Introduction and Methodological Justification

This paper is about the use of history by Mach and Duhem as a way of thinking critically. This is a topic that has been discussed several times (Hiebert 1970; Sebestik 1998–1999; Brenner 2019; Guzzardi 2021), but I want to consider it from a different perspective. I will confront their views on history with a particular text by Heidegger which deals also with history as a subject. The text is Heidegger's habilitation conference, pronounced in Freiburg in 1915 and published in 1916 in the *Zeitschrift für Philosophie und Philosophische Kritik*, entitled "The Concept of Time in the Science of History". So, the topic is not properly history, but time (the concept of time). However, in it he reveals a particular vision of history that I would like to confront, compare and use to rethink Mach's and Duhem's views. My main aim is to understand history the way Mach and Duhem use it through the lenses of Heidegger's early views in order to contrast different uses of history at the beginning of the 20th century.

My procedure will be to follow closely Heidegger's text, and contrast it with some assertions by Mach and Duhem, trying to handle the different perspectives of the three authors. At the end I will try to present some conclusions showing how the way Mach and Duhem used history provides a genuine philosophical tool in order to understand science critically.

My methodological choice of Heidegger's text is the following: Duhem and Mach died in 1916 and Heidegger published his Habilitation conference that same year (although the conference was pronounced the previous year). The coincidence of dates –trivial as it may appear—shows, in a certain way, contemporary but different conceptions of history that are representative of the transition from the 19th to the 20th century. The perspectives are very different, since that of Heidegger is an earlier conception, different from the views that he would hold later in his more mature works. By 1916 he had not yet published the works for which he would become a famous and prominent philosopher. This text, nevertheless, shows some worries that he inherited from famous predecessors such as Dilthey, Rickert and Windelband. One of this is the distinction between natural and human sciences ('Naturwissenschaften' und 'Geisteswissenschaften') which is patent in this text.

It might surprise, at first, the use of Heidegger's work to rethink Mach and Duhem, given the fact that their views are so different. The trivial coincidence of dates that I mentioned above, in fact, is not the main reason to use this text, since Heidegger's views cannot be regarded as strictly contemporary, considering that Mach's and Duhem's conceptions were developed earlier, during the last third of the nineteenth century and the first decade of the 20th.[1] However, the problem of the divide between the natural and the human sciences has

[1] It is also relevant to mention that Heidegger developed important views on time in *Sein und Zeit* and in the famous Marbourg lecture "Der Begriff der Zeit". However, as I am only using Heidegger's Habilitation conference as a methodological tool, I will not

long roots in the nineteenth century and part of the discussion about it developed during the time in which Mach and Duhem wrote their views on history of science. In this regard, Heidegger expresses a nearly contemporary view, in the sense that his text shows the spirit of an epoch, that of the transition from the 19th to the 20th century regarding the topics concerned here. And he does it from a different perspective, on a topic common to the three of them: that is history. Also, Heidegger takes the concept of time in physics in order to oppose and compare it to the concept of time in history. Considering that both, Mach and Duhem were prominent physicists and wrote about the history and philosophy of physics, the comparison with Heidegger's view might bring some interesting conclusions.

Also, Heidegger's is a rich text and there are many reasons to consider it. I will try to provide some. I want to start by considering the very first paragraph, and paying attention to some of the expressions used in it:

> For some years now a 'metaphysical urge' has been awakening within scientific philosophy [wissenschaftlichen Philosophie]. Remaining focused on mere epistemology will no longer do the job. The emphasis on epistemological problems is born of a legitimate and lively awareness of the need and value of critique, but it does not permit philosophy's questions about ultimate issues and goals to achieve their intrinsic significance. This explains the sometimes hidden, sometimes manifest tendency toward metaphysics. We should interpret this trend as evidence of a deeper understanding of philosophy and its problems, and we should see in it philosophy's will to power, although certainly not in the sense of the intellectual violence of the 'worldview of the natural sciences'. (Heidegger, 1916/2007, 61).[2]

First of all, the idea of "scientific philosophy" (wissenschaftlichen Philosophie) might strike our reading. It is not clear what Heidegger means by this expression (since he does not make it explicit), but it may surprise a bit, given that this will be the name to be attributed later to the Neopositivistic philosophy of the Vienna Circle and its followers. As such, it could look as if Heidegger was foreseeing the road that philosophy would take just a few years later. But in fact, it is a not so uncommon expression at the time, since we find it in the French context as 'philosophie scientifique' as early as 1848 in Ernest Renan's work (1848/1995, 301). Also, in the German context it is an expression linked to Richard Avenarius's journal *Viertel Jahrschrift für wissenschaftliche*

consider these works, since a full discussion of Heidegger's conception of time and history and a full comparison of his mature views is beyond the scope of this work.

[2] I quote from the English translation of the texts, but I have confronted translations with original texts and I will introduce correction or the original expressions when required.

philosophie founded in Leibzig in 1877. In fact, the idea of a scientific philosophy as opposed to a very speculative natural philosophy (*Naturphilosophie*) appeared in the German academic community as a reaction to idealism.

To Heidegger, this scientific philosophy is clearly associated with epistemology, understood as a critical theory of science.[3] However, this scientific philosophy seems insufficient without metaphysics (understood as First Philosophy), because it cannot attain the most important philosophical questions. This could be of course subjected to many criticisms, and one can find many explanations of this assertion, such as Heidegger's opposition to Neo-Kantian philosophy and to its emphasis on epistemology (cf. Köhnke 1991, 3). And one could also discuss the role of metaphysics and epistemology in philosophy, but this will lead to the usual discussions and common places in Heidegger's philosophy and I am not interested in that. I will only retain the idea that he is very conscious of the philosophical moment in which he is immersed: the striking development of the natural sciences during the nineteenth century has a strong impact on the beginning of the twentieth and they permeate and, in some ways, even dominate several aspects of the culture of the time. In a sense, Heidegger saw this advance of the natural sciences as a kind of danger or threat, given that he expressed this by stating that the natural sciences exert a 'violent worldview', hence the urgent necessity to put forward a specific place for the human or cultural sciences (Safranski, 1994, 52). Heidegger, hence, established history as one of the most prominent representatives of human sciences, and so he wanted to show the specific and irreducible temporality of historical science compared to that of the natural and mathematical sciences.

However, Heidegger's 'metaphysical urge' for scientific philosophy is in clear contrast with the following assertion made by Mach: "In it [his work on the Principle of energy conservation] every *metaphysical* and every one-sided *mechanical* view of physics were kept away, and an arrangement, according to the principle of the economy of thought […]" (This is from the preface to the second edition, published in 1909). Mach can very well be considered as one of the representatives of the so-called (by Heidegger) 'scientific philosophy' –in fact, assertions like this will have a strong impact on the first views of the members of the Vienna Circle and their scientific philosophies. Despite being a scientific philosopher, and contrary to Heidegger's assertion, Mach really does not seem to have any kind of 'metaphysical urge', as is clearly expressed in that quotation and in several places of his works. Quite the contrary, metaphysics, to Mach, is part of the problem of the current state of the sciences and it is precisely one of his aims to free science from metaphysical assertions because of their lack of ground and their lack of a 'firm' scientific basis:

> The ultimate unintelligibilities on which science is founded must be facts, or, if they are hypotheses, must be capable of becoming facts. If the hypotheses are

[3] This is also an association to the Neokantian school of Marburg, in which epistemology was prominent. After all, Heidegger was a student in Marburg, with Natorp.

> so chosen that their subject (*Gegenstand*) can never appeal to the senses and therefore also can never be tested, [...] the investigator has done more than science, whose aim is facts, requires of him –and this work of supererogation is an evil. (Mach, 1872/1911], 57)

This quotation expresses Mach's positivistic position that has also been subjected to many criticisms. But what is interesting to stress for our purposes, is the idea that scientific research has some limits, and it is harmful to go beyond them because it does not help at all in the advancement of scientific research or, in short, of science. Also, besides the positivistic appearances it is interesting to underline the following view on facts:

> Let me add a view on scientific theories in general: If all the individual facts –all the individual phenomena, the knowledge of which we desire– were immediately accessible to us, a science would never have arisen. Because the mental power, the memory, of the individual is limited, the material must be arranged. (Mach 1872/1911, 54)

So, despite the positivistic insights we have to consider Mach in a much more complex way: the scientist has to look for the facts, which are the building-blocks of science, but he does not passively receive them. The scientist takes part: facts have to be ordered, as he says "the material has to be arranged", and that is also the role of the scientist, to take an active part in that arrangement. But that does not mean that the scientist goes beyond the subject of his science, beyond the call of his duty, searching for something that cannot be tested.

Also, when contrasting this position with Duhem's, we should mention that his attitude towards metaphysics is very different from that of Mach's, however, when considering science (physics in this case), he asserts: "No metaphysics gives instruction exact enough or detailed enough to make it possible to derive all the elements of a physical theory from it" (Duhem 1906/1962, 16). So, despite the differences, both Duhem and Mach agree that metaphysics is not the ground of science. In fact, Duhem asserts that "the metaphysician should know physical theory in order not to make an illegitimate use of it in his speculations" (1906/1962, 291). We will show the striking contrast that this position has with Heidegger's. Therefore, to Mach there is no place for metaphysics at all, whereas to Duhem, there is no place for it within science, it has a proper and legitimate place, but it does not help in making science clearer or in solving its problems. Knowledge, to Duhem is not a hierarchy with metaphysics lying at its basis.

Heidegger, on the contrary, thinks that it is urgent to metaphysically ground science, because it is the only way to establish an ultimate foundation and solve the problems of a science. Epistemology "will no longer do the job" because it is the task only of metaphysics to solve the ultimate issues and goals. Of course, this implies a very particular and specific view of science: the

requirement of a metaphysical foundation under any epistemological assertion is seen as the only way to solve the problems of science in order to "undertake the comprehensive future task of a general theory of science" (61). So, even though Heidegger's more immediate purpose, as shown in this text, is to display and emphasize the difference between natural and human sciences, his long-term aim is to solve all the problems in science by establishing firm metaphysical grounds in order to create a general theory of science valid and applicable to every science.[4] This may sound a bit strange since, as it is well known, to many authors of the time, the excessive number of metaphysical assertions in the sciences is precisely the source of many of the problems present in them and this caused the worries of neo-Kantians and positivistic philosophers as well, as we have shown in Mach's position. But in any case, this just means that to Heidegger, metaphysics is not the problem, but the solution. Hence, the necessity of providing a different view that is able to oppose "the intellectual violence of the 'worldview of the natural sciences'". This novel view implies the consideration of the 'essence' of the sciences, as we will see.

8.2 Heidegger on Science

Before entering into Heidegger's considerations on history, I would like to elaborate a little bit more on Heidegger's view of science in this text, since it will be necessary to understand it for the discussion, and he himself places at the beginning some general considerations on science and the theory of science, i.e. logic. He asserts that "every science is a coherent interconnection of theoretical cognitions organized and grounded on principles" (61). This is a very conservative view, although not so uncommon at the time,[5] one which acknowledges only the theoretical structure of science and does not take into account any practical considerations. Sciences are sets of principles which express knowledge, because they are valid. So, "considered in terms of the idea of its completion, each science is a self-subsisting coherence of valid sense" (62). Thus, apparently, the sciences are completely independent of one another and self-contained. However, against this idea, he immediately adds: "But as temporally conditioned cultural facts, the particular concrete sciences

[4] This aim might not be coincident with Heidegger's mature project regarding the existential conception of science, where the role of regional ontologies governs scientific inquiries and domains. Instead of a general theory of science, he aimed at a fundamental ontology, related to those regional ontologies. Again, the discussion of these views is beyond the scope of this paper, since a dialogue with Heidegger's mature conception is not the object of this text.

[5] For example, Duhem and Poincaré stressed the role of theory in science. Cf. Duhem, 1906, the focus on theory is already shown in the title *The Aim and Structure of Physical Theory*. And Poincaré (1902), particularly chapter IX. But there are also much more practical views, such as Mach's, who in his work on *The Science of Mechanics*, begins the analysis of science with the practical use of instruments such as the lever. For a consideration of the practical approach to physical science in Mach see de Paz (2018, esp. 227-237).

are never complete but always in the process of discovering truth" (62). So, there appears to be two kinds of science or two ways of understanding science. The first one could be considered as "Science" (with capital 'S'), this is what might be understood in terms of its completion and is also self-subsisting or self-contained. But this is only a very theoretical idea, in the sense that it really does not tell anything about science. It is like an ideal never to be attained. It is something so independent, so isolated that it cannot in any way fulfill any concrete idea. It is something that we can hardly speak about; we cannot really say anything about it. It is so self-contained that we cannot even say regarding what it is supposed to be valid. Thus, as we cannot say anything relevant of this "Science" (with capital 'S'), we should consider the other "science" (with small 's'). This science is particular, concrete, incomplete, in process and temporally conditioned. So, it really is much more interesting than Science (with capital 'S') and there are many things that can be said about it. And it also looks much more interesting to Heidegger himself since that is on what he focused.

So, whatever the structure, aspect or aim of Science (with capital 'S'), he concentrates on the particular sciences. Each particular science has a *method*[6] –that is, a way to discover knowledge. The method is determined by the *object* of the science, which is the domain of knowledge that science is about. And in order to attain that object (knowledge) the method operates with *concepts*. It is precisely the task of a general theory of science to understand the logical *structure* of those concepts. So, the general theory of science will provide the metaphysical grounds for the particular sciences. This will be the 'correct' epistemology grounded on metaphysics, not the 'mere' epistemology that he quotes at the beginning.

Particular sciences are so limited in their purposes that they are not able to determine the structure of their own concepts, nor can they research and reflect on their proper methods and they need this general theory to tell them what to do. So, properly speaking, the task of a general theory of science is to be normative for the particular sciences. The researchers in particular sciences can only deal with those tasks (thinking about their methods and concepts) when they move to a different perspective, stop researching their particular sciences and "start to do philosophy" (62). So, philosophy is normative regarding the sciences, and even if Heidegger in this text does not deny to scientists the ability to do philosophy, they will only do that when they stop to do science and start to do philosophy. Philosophy and science are thus completely detached from one another. From this perspective, in some strange sense, philosophy is so alien to science that it becomes difficult to understand how philosophy could tell anything at all about science, or how it can develop a general theory of science. It has to be a second-order reflection about science, but of course, more fundamental, previous in some way, because of its prescriptive character.

[6] What I write in italics here are words in italics in the German original and in capital letter in the English translation of Heidegger's text.

So, to Heidegger, philosophy is able to tell the particular sciences the logical structure of their concepts and thus the proper method of research, and all that from a theoretical point of view and without any interaction with the real practice of those sciences (philosophy is indeed weirdly expert!). In order to understand philosophy's task as a general theory of science which provides the logical structure of scientific concepts, it would be useful to clarify Heidegger's conception of logic in this text.

As part of his inheritance of nineteenth century conceptions, Heidegger's notion of logic is connected to Neokantian ideas. In a general sense, as Käufer has stated, Heidegger's conception of logics is this: "Logic grounds in metaphysics and is itself nothing other than the metaphysics of truth" (GA 26: 132, quoted in Käufer 2005, 141). This view explains the 'metaphysical urge' stated at the beginning of the text. If the task of a general theory of science is to understand the essence of particular sciences, and if this general theory is also called logic by Heidegger and if logic is grounded in metaphysics, then the necessity of metaphysics is patent to Heidegger's task. It is this logic which determines the essence of a science by making explicit its proper goal as a science. Once this goal is established, the structure of the concepts of this science is clarified by the function they have in the attainment of the goal of the science.

This conception of logic as the study of the relations that the concepts of a science have with the goal of that science is a classical conception in the history of philosophy, when logic was not a set of formal languages in order to model and articulate our thought. Logic was indeed about "the most general relations that obtain among the most basic concepts of science" and its aim was to answer questions regarding the origin of thought or the relation between number and time (Käufer 2005, 142–143).[7]

Contrasting with this theoretical perspective on science, we would like to bring into play the following standpoint:

> In the investigation of nature, we always and alone have to do with the finding of the best and simplest rules for the derivation of phenomena from one another. One fundamental fact is not at all more intelligible than another: the choice of fundamental facts is a matter of convenience, history, and custom. (Mach 1872/1911, 57)

According to this, although the aim of science is the interconnection of phenomena economically arranged, this perspective expresses a dynamic view in the sense that there can be no definitive determination of what is science if it is grounded on facts and the choice of facts depends on variable and unfixed

[7] Käufer also describes that Heidegger, from 1919 on, and especially after *Sein und Zeit* departed from the conception of logic more attached to the Neokantians, since to them the task was more epistemological and they had to study the sciences, but the connection between logic and metaphysics seems to be constant, although takes different shapes through Heidegger's career.

ideas such as convenience, history and custom. So, science is always conceived as a process and to Mach, it cannot be seen from the "idea of its completion", since convenience, history and custom are variable criteria. This idea of science fits with Heidegger's perspective of the particular sciences: they are particular, concrete, incomplete, in process and temporally conditioned, and as such, subjected to convenience, history and custom. The difference is that there is no other 'Science' to Mach, there is no possibility of establishing a general and complete theory: "the systematization of knowledge is certainly unavoidable, but it plays a subordinate role when science is conceived as a process" (Schnädelbach, 1983, 113).

Regarding this same topic on the perspective of science and on the relations between science and philosophy, the following passage from Duhem's *Aim and Structure of Physical Theory* is worth quoting *in extenso*:

> Ever since the most ancient speculations known to us, philosophy had been inseparably linked with the science of nature [physics] and with the science of numbers and shapes [arithmetic and geometry]. A few hundred years ago, this linkage, some thousands of years old in uniting philosophy first to natural philosophy, looked as if it had been weakened to the breaking point. Leaving to the mathematician and the experimenter the task, daily becoming more detailed and more difficult, of working for the advancement of the particular sciences, the philosopher took as the exclusive objects of his reflections the most general ideas of metaphysics, psychology, and ethics; consequently, his thought seemed lighter and more apt to rise to heights which wise men had not been able to reach till then, burdened as they were with so many branches of knowledge alien to their true and noble study.
>
> Rid of mathematics, astronomy, physics, biology, and all the slowly advancing sciences [sciences à la marche lente] with their complicated techniques and barbarous terminology unintelligible to the uninitiated, philosophy took the form of an easy doctrine, accessible to the multitude, and skilful in formulating its teachings in an eloquent language understandable by all educated men.
>
> The vogue of this separated philosophy did not last long: farsighted minds did not take long to discern the vicious principle which the seductive externals of this method scarcely concealed. No doubt, this philosophy seemed light and different from the ancient wisdom held down by the enormous weight of scientific detail, but if philosophy now appeared to fly off with the slightest effort, it was not because its wings had become longer and more powerful; it was simply because it had emptied itself of the content to which it owed its solidity, and because it had reduced itself to a vain form deprived of matter. (Duhem 1906/1962, 312)

In this passage Duhem vindicates the relevant connection of philosophy and the sciences in order for it not to become 'a vain form deprived of matter'. This reference about the interplay between science and philosophy provides a particular perspective on both: not only philosophy becomes deeper in its

content when related to science, it becomes also particular, concrete, incomplete, in process and temporally conditioned, since that is precisely what science is, because sciences are slowly advancing (*marche lente*), sciences are in progress, and if philosophy is related to the sciences, there is no possibility of establishing a general theory of science which contemplates the sciences from the idea of their completion.

Hence, neither Mach nor Duhem defend the existence of a general theory of science. This may imply a different conception of logic from that of Heidegger. Indeed, they never assert that logic is grounded in metaphysics and they probably would not subscribe that. However, the Neokantian idea that Heidegger subscribes in this text, may in some sense be present in the ideas of both scientist-philosophers. Certainly, Duhem holds a specific conception of logic within physics, holding that the main structure of the theory is deductive (1906/1962, 311), and also that the logical deduction of empirical consequences is one of the stages of a physical theory (Duhem 1906/1962, 44–46). He holds, nevertheless, a wider conception of logic in the sense of that which gives a coherent structure to a theory. A well composed physical theory has an internal structure where its concepts hold intelligible relations. Hence without the metaphysical basis Heidegger requires for logic, Duhem's general logic can also be understood as a conception in which the concepts have a structure in light of their function, given the aim of physical theory. The main difference is that the logic of physics cannot be attained without physics, and that the physicist, even when doing philosophy, has to be in deep contact with physics, in order to avoid making abuses.

The case of Mach is, nevertheless, different, since the specific role of logic is seen, in general, as more pragmatic and instrumental. However, concepts, as mental symbols, are adopted because they are useful (Gori 2014, 127) in order to satisfy certain needs, whether empirical or intellectual. In this sense, concepts have a function (its usefulness to solve a determinate problem), which determines its place in the theory. This is a logical structure stating the relations of concepts in a theory, and given that, to Mach, scientific theories are constructed to resolve determinate problems, the similarity with Duhem's views in this regard is also patent. The main difference is that they do not seem to defend an essence to the science of physics that can determine its unique aim, but I will discuss this in the next section.

Therefore, both, Mach and Duhem have a very dynamic view of science, not related to the static idea proposed by Heidegger with his aim of a general theory. Their views are nonetheless coincident with Heidegger's conception of particular sciences, although they do not require a general conception in order to provide the science its aim and especially they do not consider that a philosophical perspective detached from science is able to provide such aim. Despite the limitations of Heidegger's perspective, it will not be useless to go a bit longer considering his conception of time for the science of history, but before, I will delve into what he says about time in physics.

8.3 Heidegger on Time in Physics

The general theory of science operates logically with categories (*concepts*) and in the text, Heidegger chooses to focus on one of them, that is on the concept of time. This concept is so important because it allows showing the specificity of human sciences with regard to natural sciences. Being a concept present in both, the determination of the logical structure of the concept of time in the science of history enables Heidegger to stress the fundamental role of human sciences in culture, highlighting the specificity of historical science.

Heidegger's central question is: "What path will most surely lead to understanding the logical structure of the concept of time in the science of history?" (1916/2007, 62) The central idea is thus to problematize the concept of time and to determine its specific structure in a particular science, that is history. As it is a concept functioning in a particular science it has to work according to the proper tasks of that science. "Consequently the *structure* of the time-concept within the science of history can be described from its *function* within that science, in turn, its particular function can be understood from the *goal* (*objective*) of that science" (1916/2007, 62). The path (*method*) to follow is from the *goal* to the *structure* through the *function*. Thus, first of all the goal of history as a science has to be determined, then the function of the concept of time will be expressed in order to show its structure.

However, despite the theoretical character that Heidegger has attributed to science at the beginning of the text, he does not want to consider any theoretical presupposition regarding this topic and asserts that he will take as his point of departure the *factual* character of history, he will study history as a *fact*: "If we solve the problem as posed [as a fact] and come to understand the concept of time as one of the central concepts within historical science, we should be able to establish some general principles about the logical structure of history as a science" (1916/2007, 63). The procedure proposed is indeed a kind of positivistic one; he applies the inductive method: from the facts to the general principles. In spite of this inductive intention, the real procedure that Heidegger decides to take is indeed a bit different. In order to show the specificity of the concept of time in the science of history, he compares it with the concept of time in the natural sciences, specifically in physics: "*Within physics, what structure must the concept of time have in order to function as a concept of time that corresponds to the goal of physics?*" (1916/2007, 63).

To Heidegger, the goal of physics should be considered from the modern times, that is, from Galileo, because it is since Galileo when the goal of this science becomes clear. Before Galileo, in Medieval and Ancient times, the goal was "to investigate the metaphysical essence and hidden causes of phenomena as these latter obtrude in immediate reality" (63). Physics was then a metaphysical science not related with its modern form. But with Galileo a new method arises and then physics "seeks to master the multiplicity of phenomena by means of laws" (63). The most important feature of this new

method is how the scientist arrives at those laws, and this is really the establishment, to Heidegger, of the method of modern science, which is precisely the hypothetical-deductive method. The scientist proposes a hypothesis, a general assumption, as a possible explanation of phenomena, he tries to test it with concrete phenomena and if they confirm the assumption, then it is considered valid "and from it one derives, by pure deduction, the law that is subsequently corroborated by experimentation" (64). The law is then a universal hypothesis.[8]

> Two things are peculiar to this new method: 1. It sets out a hypothesis that allows us to understand all the phenomena of a peculiar region. 2. Rather than positing some hidden quality as the cause that explains the phenomena the hypothesis consists of mathematically understandable (i. e. measurable) relations between idealized moments of the phenomenon. (64)

With this assertion Heidegger makes clear the fundamental feature of physics as a science: it explains the phenomena in terms of mathematical relations expressed in the form of equations.[9]

At this point we want to praise Heidegger's acquaintance with the science of his time: "The multiplicity of particular fields within physics has nowadays been reduced to two: mechanics and electrodynamics, or (as it is sometimes put) the physics of matter and the physics of the ether" (64). The date is, as we recall, 1916, and although Einstein's general theory of relativity has already been published (in fact, Heidegger will mention it later on in the text), the problems between the old and the new physics are still at stake. And to show this, he quotes Planck: "Laying a foundation for mechanics requires, in principle, only the concepts of space, time, and 'the mobile' whether considered as a substance or a state. These same concepts are also indispensable for electrodynamics. Thus a sufficiently generalized mechanics could easily take in electrodynamics as well; and in fact there are many indications that these two fields, which already partially overlap, will ultimately be unified into a single field: general dynamics" (Planck 1910, 117).

[8] Heidegger takes Galileo's discovery of the law of free fall (Auffindung des Fallgesetzes). The English translation speaks about "Galileo's discover of the law of gravity", which is not the same, since the law of gravity is Newton's law of attraction. Heidegger takes this discovery as an example of the hypothetical-deductive method, but this was not the procedure used by Galileo. He presupposed that there was a mathematical relation that could explain the phenomena, but he did not presuppose what this relation was in the hypothetical way described by Heidegger. He arrived at the correct law from the experiments of the inclined plane. (Drake 1999, v. 2)

[9] The idea of the mathematization of modern science is the method usually attributed to Galileo, and the beginning of modern science is linked to this idea since long time ago. Probably Heidegger is confusing mathematization with hypothetical-deductive method, and that may explain his inaccurate account of Galileo's law of free fall.

Planck's quotation enables Heidegger to reveal the ultimate goal of the physical science, which, with its new method of establishing mathematical relations, is "the unity of the physical theory of the world, the reduction of all phenomena to the mathematically established basic laws of general dynamics –laws of motion that apply to any mass that needs to be determined" (65). So, the goal of physics is to bring all phenomena under the laws of motion, which of course, is a kind of mechanistic reductionism, something that the 20th century will not fulfill, but still a common position by 1916.[10]

Now, recalling the method of the general theory of science: from the *goal* to the *structure* through the *function*, in order to uncover the structure of the concept of time in physics, its function has to be determined. Since the goal of physics is the explanation of motion by means of laws, motion has to be measured, and it is measured in time. To determine motion, we measure its displacement through space in time. Heidegger asserts that "measuring as a way of determining quantity is the business of mathematics" (65). This is a very restrictive view of mathematics that accounts only for a technical dimension, and of course it cannot explain many developments in modern (and not so modern) mathematics. In contrast, we can quote Boole's work, published almost sixty years before Heidegger's, denying precisely the assertion that mathematics is just the science of the quantity or magnitude:

> The abstractions of the modern Analysis, not less than the ostensive diagrams of the ancient Geometry, have encouraged the notion, that Mathematics are essentially, as well as actually, the Science of magnitude.
>
> The consideration of that view which has already been stated, as embodying the true principle of the Algebra of Symbols, would, however, lead us to infer that this conclusion is by no means necessary. If every existing interpretation is shown to involve the idea of magnitude, it is only by induction that we can assert that no other interpretation is possible. And it may be doubted whether our experience is sufficient to render such an induction legitimate. (Boole 1847, 4)

Heidegger's acquaintance with the science of his time although more or less updated in physics is more than restricted regarding mathematics, since, to take on Boole's statement, algebra of logic is precisely a counterexample of a mathematical discipline not dealing with quantity, but with relations.[11] But

[10] As the reader probably knows, by 1905 Einstein had resolved the incompatibilities between mechanics and electrodynamics in the special theory of relativity and eliminated the ether. Planck knew about it, given that Einstein's paper was published in *Annalen der Physik*, of which Planck was an editor. But general dynamics should include also a theory of gravitation, and the unification of electrodynamics and gravitation has not happened yet. By that time, also, Planck had already discovered the *quantum hypothesis*, and this will change definitely the face of physics.

[11] During nineteenth century mathematics progressively transforms from the conception of the science of quantity to a science of relations, and Boole's position is part of this movement of transformation. Cf. Ferreirós 2023.

this very limited view of mathematics as a science of quantity is useful to him in order to connect mathematical physics with phenomena in a simple way: to get precise concepts, they have to be studied in their mathematical form and in this particular case this means quantification. So, the concept of time in physics has to be quantified to be understood; it has to be transformed into some 'measurable' quantity. Thus, the *function* of the concept of time in physics is simply "to make measurement possible" (66). And once the function is clear, we can deduce which the *structure* of the concept has to be: it has to flow uniformly, in a way that "time is like a simple linear series in which each point of time is differentiated by its current position as measured from its initial position" (66); "Time has become a homogeneous ordering of points, a scale, a parameter" (66). So, its structure is that of a homogeneous and quantitatively determinable parameter. The only difference between one instant and another instant as parts of the same time is the position it has in the succession, that is the position it occupies in the line.

In order to keep showing that he is acquainted with the physics of his time, Heidegger quotes the conception of time in Einstein's relativity theory, but he asserts, that neither this theory, nor any other physical theory is concerned with the concept of time itself, but only with its measurement: "Nothing could more clearly express the mathematical character of the concept of time within physics than the fact that time is posited as the fourth dimension alongside three-dimensional space, and, together with it, is treated in a non-Euclidean geometry, one with more than three dimensions" (67). So, mathematics as a science of measurement and physics as a mathematical and mathematized science do not deal with the concepts themselves (the concept of time in this case), but only with their measurements. This conception is coherent with the idea that the object of physical science is to reduce phenomena to mathematical laws expressed above, but it can be questioned whether this is the essential goal of physical science.

Comparing Heidegger's views to Mach, we find that the aim of science is to establish the connection among phenomena (1872/1911, 9), and physics does this in a limited and specific domain. This domain is what researchers have established as physical, that is it is not a fixed domain, but it is dependent on what Mach calls the 'direction of research' (1914, 18), which in physics is usually linked to what we call 'external phenomena'.[12] Hence, the goal of physics is to find out relations and bring them under convenient and functional laws. This of course could be mathematical laws, as Heidegger proposes, but the aim of establishing these connections is to improve our adaptation to the world, and this does not necessarily imply a mathematical reduction. As the aim of science for Mach is our orientation in the world (Mach 1914, 37),

[12] Although given Mach's neutral monistic position there is not a difference between the internal and the external world, the phenomena that do not depend on the ego and that we usually call external are those linked with the science of physics. See de Paz 2025, 1246–1251 for an epistemological defense of neutral monism.

mathematization is only useful insofar as it contributes to achieving this aim, and other forms of orientation remain possible. It might well happen that a different understanding of time than that of measurement provides a better orientation, then the scientist should find a different one.[13] In fact, it is well known that Mach conceived mechanics and the reduction of all phenomena to the laws of motion as one of the images of science and not the necessary one.

Duhem's view of physics fits better with Heidegger's, since the establishment of symbolic laws to represent phenomena is the aim of physics. However, Duhem states that every physical theory should aim at a natural classification in which the logical order of the theory is coincident with the ontological order of reality (1906/1962, 32ff). This is only an ideal and it is never attained but it shows a certain aim at intelligibility in the natural science that goes beyond the idea of instituting only mathematical laws to account for phenomena. Also in this sense, the broader aim of science may account for a different function of the concept of time within the theory, and hence for a different structure that implies a role of intelligibility and not only measurement.

In any case, for Heidegger it is impossible to extract any universal feature of the concept of time from the scientific conception in order to derive a logical category that could be applied to other sciences. In fact, "within scientific history, time is not unlike an ordering of points, whereby events get their determinate place in time and are thus fixed *historically*" (67). So, physics is not able to determine the concept of time in its own history, probably because to Heidegger, the history of science belongs to the domain of history and not to science, hence the separation between natural and human sciences. The concept of time in physics as a quantitative one with its homogeneous, regular and scalar structure cannot help in the determination of the concept of time in history. Knowledge of natural science does not help in the understanding of human sciences. As a result, the concept of time has to be determined "from the essence of the science of history" (67).

8.4 Heidegger on Time in History

Continuing with the idea that the proper method of logic as a general theory of science is from the *goal* to the *structure* through the *function*, Heidegger must determine the goal of history. As such, he states the domain of knowledge for historical science: "The object of the science of history is human beings, not as biological objects but insofar as their intellectual and material achievements serve to actualize the idea of culture" (68). This assertion makes the divide between natural and human sciences even clearer. History belongs

[13] I do not want to enter on the different conceptions of time held by Mach from the physiological and from the physical perspective, since this will be beyond the scope of the paper. I just want to point out that his conception of science offers different possibilities than mathematization.

to the human sciences, and it is about humans as cultural beings, its domain of knowledge is culture as a human creation. It is also clear that, for Heidegger, science is not part of culture.

Historians thus deal with cultural events, but not every event is historically relevant; as Heidegger says, "historians are interested only in what is 'historically efficacious [historisch Wirksame]'" (68).[14] But what does efficacy (or effectiveness) mean from a historical point of view? According to Eduard Meyer, as quoted by Heidegger, "The selection depends on the historical interest that the present has in this or that effect, this or that outcome of the development" (68). What is considered historically effective is what matters in the present, what is important for the culture of the time that shapes history. History is thus interpreted teleologically from the present. History is not simply the chronological account of events as they follow each other in time, but rather the understanding of the significance that those moments have for the present. The present moment determines which moments are historically relevant and, this implies a criterion or an interest. According to Heidegger, every interest is "determined by a point of view and guided by a norm" (68). As a result, the determination of what is historically effective depends on certain values.

Heidegger is now in a position to make explicit the *goal* of the science of history: "to present the interactions and development of objectifications of human life in all their singularity and uniqueness as they are understandable in their relation to cultural values" (68). So, properly, history deals only with objectifications of human life, and it presents them according to certain values, the values of a culture.[15] These 'objectifications' are, as mentioned before, the intellectual and material achievements of human beings, and those achievements are interpreted in terms of cultural values; their relevance depends on the point of view of a culture, and on the norms of that culture. The relative character of history is thus revealed through its values, hence its distinctness from natural sciences where the determination of concepts was not, apparently, dependent on any values.

After the determination of the goal, Heidegger remarks on what he understands as an essential mark of the historical object: it is always past. "The past has its meaning always and only when seen from the present" (69). Thus, no historical object can have a meaning without the consideration from the present perspective, from the point of view of the culture of the present moment. This means that, from this viewpoint, there is no way of understanding history without being anachronistic. According to Heidegger "a

[14] It may also be translated as 'historically effective'.

[15] Here the influence of Windelband is clear, since to him, the assessment of a historical fact, depends on what is valuable to us. This idea was taken up by his student, Heinrich Rickert, who developed "a systematic account of the "individuating" and "value-relating" "concept-formation" of the "historical sciences of culture"" (Kinzel 2024). As is well known, Heidegger was Rickert's assistant and wrote his habilitation thesis under him (Luft, 2015, 461).

temporal divide separates the historian from the past" (69). And, it is explained in this way: "When viewed from our standpoint, the past not only no longer *is*; it also *was* something other than we and our present-day context of life are" (69). This simply states that what is past, is exactly that –past– and that it is different from everything that now is (from the present). But Heidegger goes on, to stress that "time has a completely original meaning in history" (69): "Only when this qualitative otherness between past times and the present moment breaks into consciousness does the historical sense awaken" (69). So, only when we are aware that what is past is different from what is present *does* history become possible. But this difference, this 'otherness' is not completely alien, because as cultural beings and with history as part of culture, we live amid those objectifications of the past. Thanks to this proximity, we are able to situate ourselves in front of the historical object in order to 'overcome the temporal divide'. The existent gulf between the present and the past can only be overcome when "time itself assumes its function with scientific history" (69). So, once we have the goal of historical science in mind (to understand the past as cultural past), Heidegger has to make explicit the proper *function* of the concept of time in order to understand its *structure*.

In order to analyze the function of time, he devotes some space to the method of history. Thus, he exposes the two main tasks of the science of history. The first is to guarantee factuality [*Tatsächlichkeit*]; this is done by checking the authenticity of the source. This is what Heidegger considers is the aim of criticism. So, to him, the criticism of history consists in the positivistic task of verifying the authenticity of the source, the object, or the document from which the historical information is extracted. This simple idea of criticism is in striking contrast with the alleged positivistic position of Mach and his display of the historical-critical method when asserting that:

> We believe, rather, that it can do us no harm to know the point of view of another eminent nation, so that we can on occasion, put ourselves in a different position from that in which we have been brought up. The essence of classical education is historical education. (Mach 1872/1911, 17–18)

For Mach, history provides the opportunity to situate ourselves in a different standpoint, and that is the fundamental role of criticism of history. Indeed, even when considering that scientific concepts, for Mach are variable and are nothing else than functional labels which simplify the transmission of knowledge without any truth value (as shown in his study of the history of mechanics), those concepts are rich in content because they are full of history and experience (Paty 1986, 200). History, in fact, enriches concepts and its critical task is not restricted to check the accuracy of the documents but to offering new possibilities from which we can rethink the current moment, or, more concretely, the current state of a scientific discipline.

When considering Duhem's perspective, history is also important to understand the genesis of the concepts. He considers that "hypotheses are not the

product of sudden creation, but the result of progressive evolution" (1906/1962, 220). History shows the slow process of science. Even when the development of a scientific theory appears to have been rapid and sudden, history shows that there is a long preparation previous to its emergence. History thus plays also a critical role in the understanding of the concepts of a theory: "to give the history of a physical principle is at the same time to make a logical analysis of it. The criticism of the intellectual processes that physics puts into play is related indissolubly to the exposition of the gradual evolution by which deduction perfects a theory and makes of it a more precise and better-ordered representation of laws revealed by observation" (1906/1962, 269–270). History as a critical instrument helps the scientists in getting a clearer image of their theory.

But let us return to Heidegger's second task of the science of history: identifying the context in which facts occur, that is, "correctly interpreting the relevant content of the sources" (70). This involves understanding the role a particular fact plays within the context in which it takes place. So, the second task of history is the interpretation of the past.

Given these two tasks, we have to recall that Heidegger has not yet explained the *function* of the concept of time in history, which was a key element to determine its *structure*. So far, he has only asserted that "time has a completely original meaning in history" (69). He makes explicit the structure of the concept of time before explaining its function (thus, not following his own method): "the concept of time in the science of history has none of the homogeneity characterizing the concept of time in the natural sciences. That is also why historical time cannot be expressed mathematically by way of a series, for there is no law determining how the *time-periods* succeed one another" (71). Time, in the science of history is and can only be qualitative. Although history makes use of chronology, it does not operate through quantities. Yet, as the previous section indicated, it is questionable whether the natural sciences themselves are limited to quantitative considerations alone. The distinction between the quantitative and the qualitative constitutes, for Heidegger, the supposedly firm foundation upon which the separation between the human and natural sciences is grounded:

> The temporal moments of physical time are distinguished from each other only by their positions in a series. Historical periods likewise follow one another (otherwise they would not be time periods); but each one is distinct as regards is structural content" (71). And here we get the explanation: "*The qualitative factor of the historical concept of time is nothing but the congealing –the crystallization– of and objectification of life within history*. (71)

The function of time in history is the function of history itself: the understanding of the past. Time in history situates events in a qualitative line in which they are situated in relation to others according to the relevance that

they have for culture, according, thus, to certain values. There is no mathematical law able to determine historical periods. The function of the concept of time in history is to place and understand events in a historical context. The difference with physical time is that in physics each instant is only distinguishable from any other by its position; in history, although positions are also different because there is also succession, the events, the instants, are different because of their structural content, because of the place they have in a context, not in a quantitative line. There are of course temporal scales in history, but that does not mean that they are quantitative scales. In history, scales begin with a significant event, e.g. "the founding of the city of Rome, the birth of Christ, the Hegira" (Heidegger 1916/2007, 72). This relation to a particular significant cultural event shows the relation between history and values. And that is precisely the principle that regulates the formation of concepts in the science of history. Whereas in the natural sciences the formation of concepts was regulated by the aim of mathematization, of quantifying and measuring the phenomena (that is why the structure of the concept of time in physics is homogeneous and uniform, in order to facilitate measurement), in history, the formation of concepts is regulated by values. This enables Heidegger to conclude that the science of history is "an original intellectual position, irreducible to any other science" (72).

This conclusion shows, in fact, Heidegger's worry about the natural sciences dominating the field of culture and his urgent necessity to show the irreducible and original character of the human sciences, being linked to cultural values. However, he does not specify which these values are, how they are formed, or how they help or could even be a problem in our account of history –that is probably beyond the scope of his conference.

Although it is an interesting text to think about the worries of some philosophical positions at the beginning of 20th century, it offers, from our point of view, a limited assessment of history. The critical task of history consists of the checking of the documents and on its proper contextualization, but it looks as if he does not want to take a step further and show the possibilities that the analysis of history could have for the present. In contrast, for Mach, as shown by Guzzardi (2021, 165), "past achievements are not past once and for all – rather, our 'modern' views are the result of a tradition inherited from that past". This denies the idea that there is a gulf between the past and the present that needs to be overcome. Indeed, the acknowledgement of belonging to a tradition can be considered as quite similar to the understanding the past as cultural past, but Mach's conception goes beyond the recognition of a tradition by stressing the different possibilities offered by history, and hence, the critical role history plays in knowledge.

For Heidegger, it looks as if history could only situate events in the past according to certain significant moments, but it does not really offer a critical perspective for the present, as Mach thought. And it is really not clear in the text how the metaphysical urge and the metaphysical grounding could help in the task of making history an irreducible science. Regarding this, it is curious

to consider, in opposition, the following assertion by Mach: "we are accustomed to call concepts metaphysical, if we have forgotten how we reached them" (1872/1911, p. 17). For Mach, it is the historical-critical method, the historical critique which reveals the empirical origin of our concepts, which helps in recalling the basic and technical practices which lie at the basis of our abstract current concepts. The historical-critical analysis frees those concepts from metaphysical considerations by bringing them back to their origin. History, for Mach, is not just the positivistic history of events, but the history of concepts, and by studying history one can understand the history of concept formation, and that is helpful for our present considerations. In his analysis of the history of mechanics, Mach traces the origin of the abstract current concept of mechanics to practical and technical needs and links those considerations to the use of basic machines helpful in solving everyday-life problems. He links the history of science to the practical needs of the human beings. And he also shows that tracing the historical genesis of a concept enables the critical consideration of alternatives, the contemplation of the possible historical paths that the development of a concept did not take, but that given historical contingencies might have had.

A similar vision arises when considering Duhem's perspective on science. First of all, his vision of history is as something dynamic, not crystallized. In his reflections on physical science, he saw physical theories as evolving entities, not fixed, and his conception of physical theory is modeled on historical examples to show the changing perspective of science. So science is also dynamical. But what is most interesting to underline is also the critical task that history played in Duhem's philosophical position regarding science: his conception of the physical theory, his philosophy of physics in short, was modeled on historical considerations. For him, the use of historical examples was not a mere illustration of his views, but was the basis from which his considerations emerged. He considered that our theories were "autonomous and independent of any metaphysical system" (1906/1962, 334), and so the considerations on a scientific theory could be grounded on history, but not on a defined and stable metaphysical system.

Heidegger's position, however, could also be considered from the perspective of the critical consideration of alternatives, given the variability of values. If historical events are arranged according to certain values, these values could change depending on the culture one is immersed in, and on the significance of the events we are considering. In this sense, factuality is as restrictive to Heidegger as it is to Mach and Duhem. If history is narrated from the present perspective and according to the present values, it is not fixed but dynamical and it could be understood as a way of problematizing the present, the present culture, or the present of a scientific discipline. Hence, history may have a critical task.

The specificity of historical knowledge, according to Heidegger—and also to Rickert—lies in its reliance on values, which are absent from the natural sciences. Heidegger argues that physics does not concern itself with the

concept of time as such, but only with its quantification and measurement. History, by contrast, engages with the concept of time itself, insofar as it is capable of individuating events and considering them in their particularity and uniqueness. Whereas the natural sciences aim to mathematize phenomena by generalizing facts, historical understanding depends on values that enable the interpretation of the uniqueness and significance of individual occurrences.

This distinction between the natural and historical sciences can be questioned on two main grounds. First, the assumption that natural science does not interpret phenomena within a determinate context is problematic. Every experimental scientist knows that experiments require interpretation within specific conditions, and that results can only be generalized under carefully defined circumstances. As Duhem observes, a physical experiment consists of both the observation of a set of phenomena and the interpretation of those phenomena (1906/1962, 221–222). Such interpretation involves abstract and symbolic representations that depend on the theoretical framework accepted by the scientist. The central role of interpretation in the constitution of physical science therefore challenges the rigid separation between natural and historical modes of inquiry.

Second, the issue of values further complicates Heidegger's distinction. Since at least the 1970s, extensive debates in the philosophy and sociology of science have questioned the notion that natural science is devoid of values, questioning the idea that the presence of values is what differentiates human from natural sciences. Even the recognition that science is a collective enterprise—embodied in Merton's principle of communism—presupposes a value. Were science not a communal activity, the knowledge it produced would resemble that of alchemy: secretive, esoteric, and restricted to the initiated few. Consequently, the sharp opposition Heidegger draws between the factual character of natural science and the value-laden nature of historical inquiry appears, paradoxically, more positivistic than the nuanced views that recognize the historical dimension of science itself.

8.5 Concluding Remarks: The Dissolution of some Dichotomies

In his Habilitation lecture, Heidegger aimed to preserve the autonomy of history by grounding it in cultural values and stressing the temporal divide between past and present. History, for him, is irreducible to natural science because it is guided by values rather than by quantities. Yet this position, for all its insistence on history's specificity, ultimately sustains dichotomies: science and culture, nature and history, fact and value, quantitative and qualitative. History becomes, in his account, a science of contextualization—capable of situating events in relation to present cultural norms—but not a critical instrument for rethinking science itself.

Mach and Duhem reveal a different path. Their use of history resists the danger of dogmatism by reminding us that scientific concepts are contingent,

evolving, and historically situated. As Mach put it, "we are accustomed to call concepts metaphysical, if we have forgotten how we reached them." The historical-critical method brings concepts back to their origins in practice and experience, stripping them of metaphysical opacity and revealing the choices and contingencies that shaped them. In this way, history affords us the ability to step outside our inherited assumptions and consider perspectives different from our own.

History, to both Mach and Duhem, also shows the dynamic character of science. Duhem emphasized that hypotheses are not sudden inventions but the result of "progressive evolution," and that to recount the history of a principle is simultaneously to undertake a logical analysis of it. Science is never complete, never static; it advances slowly and unevenly, and history makes visible this dynamism. In contrast to Heidegger's cultural crystallization of values, Mach and Duhem highlight the unfinished, open character of scientific development.

Furthermore, history for them is a tool for evaluating the present. Past achievements are not "past once and for all," as Mach noted, but live on in the present, shaping our categories and theories. Historical awareness allows us to see not only how science arrived at its current state but also what alternatives were possible—paths not taken, but still imaginable. Such awareness opens critical space for assessing the present and imagining future directions. For this reason, both Mach and Duhem insisted that history was essential to the education of scientists (Mach 1872/1911, 34; Duhem 1906/1962, 411): it cultivates humility, critical awareness, and the imaginative flexibility needed to avoid dogmatism.

From this standpoint, the dichotomies Heidegger sought to secure begin to dissolve. The divide between natural and human sciences, between facts and values, is blurred by the historical-critical method. For Mach and Duhem, science is historical, and history can be scientific without reduction. Philosophy, science, and history are not separate domains but complementary expressions of culture. As Duhem put it, philosophy loses its solidity when divorced from science; and as Mach insisted, "let us not let go the guiding hand of history. History has made all; history can alter all. Let us expect from history all" (1872/1911, 18).

The guiding questions, then, are not Heidegger's: How do we safeguard history against science? How do we metaphysically ground its autonomy? Rather, Mach and Duhem urge us to ask differently: What becomes of time when we reflect on the history of physics — does it belong more to physics or to history? Must we force it into one side of the divide, or does its very ambiguity show the futility of the division itself? And more broadly: do we truly need to erect radical separations in order to recognize the originality of science and history, or can their integrity be preserved precisely by seeing them as intertwined?

Perhaps the answer, suggested by their practice, is no. History in Mach's and Duhem's hands is not the defense of disciplinary borders but the instrument by which borders become porous, allowing reflection and renewal. It

prevents science from becoming dogmatic, broadens our horizon of possible perspectives, shows the dynamic nature of inquiry, provides tools for critique, and plays a vital role in the formation of scientists. In this sense, history is not only retrospective but also prospective: it dissolves dichotomies by revealing science and history alike as cultural processes in perpetual motion.

Funding Information I want to thank the editors of this volume for inviting me to contribute, although I no longer work in the Portuguese community. My time in Portugal was, nevertheless, essential for my training as a philosopher of science. I also thank José Ferreirós for useful discussions about many of the topics of this article, and his patience when I was writing it. Finally, I am indebted to María J. Gutiérrez-Márquez for her inestimable help with the secondary sources.

The work conducting to the results published in this research is funded by project "The Cognitive and the Hypothethical in the Natural Sciences: Geometry, Mechanics and Space-Time", Grant Nº.:PID2021-123297N, funded by the Spanish Ministry of Science.

References

Boole, G. 1847. *The Mathematical Analysis of Logic*. New York: Philosophical Library.

Brenner, A. 2019. Mach, Duhem and the Historical Method in Philosophy of Science. In *Ernst Mach—Life, Work, Influence*, ed. F. Stadler„ 637–650. Vienna: Springer.

De Paz, M. 2018. Reconsidering Mach in the Light of the Interplay of Practices. *Revista Portuguesa de Filosofia* 74 (1): 219–246.

De Paz, M. 2025. Exploring the Mind in Austria (1874–1918) and Defending Mach's Neutral Monism. *British Journal for the History of Philosophy* 33 (5): 1242–1252.

Drake, S. 1999. *Essays on Galileo and the History and Philosophy of Science*, ed. N. M. Swerdlow and T. H. Levere, vol. 3 vols. Toronto: University of Toronto Press.

Duhem, P. 1906/1962. *La Théorie Physique. Son objet - sa structure*, trans. P. B. Wiener. Paris, Vrin. Eng, *The Aim and Structure of Physical Theory*. New York: Atheneum.

Ferreirós, J. 2023. Más allá de lo cuantitativo: el pensamiento matemático después de spués de 1850. In *Ciencia y método en los siglos XIX y XX*, ed. A. Valor and M. de Paz, 15–36.

Gori, P. 2014. Nietzsche and Mechanism: On the Use of History for Science. In *Handbuch Nietzsche und die Wissenschaften*, ed. H. Heit and L. Heller, 119–137. Berlin/Boston: De Gruyter.

Guzzardi, L. 2021. Holding the Hand of History: Mach on the History of Science, the Analysis of Sensations, and the Economy of Thought. In *Interpreting Mach: Critical Essays*, ed. J. Preston, 164–183. Cambridge: Cambridge University Press.

Heidegger, M. 1916/2007. Der Zeitbegriff in der Geschichtswissenschaft. *Zeitshrift für Philosophie und Philosophische Kritik*, 161, 173–188. Eng. T. Sheehan, The Concept of Time in the Science of History, *Becoming Heidegger: ON the Trail of His Early Occasional Writings, 1910–1927*, trans. T. Kisiel and T. Sheehan, 60–72. Evanston: Northwestern University Press.

Hiebert, E. N. 1970. Mach's Philosophical Use of History. In *Historical & Philosophical Perspectives on Science, Minnesota Studies in the Philosophy of Science, 5*, ed. R. en Stuewer, 184–213. Minneapolis: University of Minnesota Press.
Käufer, S. 2005. Logic. *A Companion to Heidegger*, ed. H. L. Dreyfus and M. A. Wrathal, 141–155 Oxford: Blackwell.
Kinzel, K. 2024. Wilhelm Windelband. *The Stanford Encyclopedia of Philosophy*, ed. E. N. Zalta & U. Nodelman (fall 2024 edition). https://plato.stanford.edu/archives/fall2024/entries/wilhelm-windelband/>.
Köhnke, K. C. 1991. *The Rise of Neo-Kantianism*. Cambridge: Cambridge University Press.
Luft, S. 2015. *The Neo-Kantian Reader*. London: Routledge.
Mach, E. 1872/1911. *Die Gesichte und die Wurzel des Satzes von der Erhaltung der Arbeit*. Prague. English—*History and root of the principle of the conservation of energy*, translated by P. E. B. Jourdain. Chicago and London, the open court publishing co, 1911.
Mach, E. 1883. *Die Mechanik in ihrer Entwickelung historisch-kritisch Dargestellt*. Leipzig: Brockhaus.
Mach, E. 1914. *The Analysis of Sensations*. Chicago: Open Court.
Paty, M. 1986. "Mach et Duhem, l'épistémologie des savants-philosophes. In *Épistémologie et matérialisme*, ed. O. en Bloch, 177–218. Paris.
Planck, M. 1910. *Acht Vorlesungen über theoretische Physik, Leipzig, S*. Hirzel.
Poincaré, H. 1902/1968. *La science et l'Hypothèse*. Paris and Reed: Flammarion.
Renan, E. 1848/1995. *L'avenir de la science*, ed. A. Petit. Paris: Garnier-Flammarion.
Safranski, R. 1994. *Ein Meister aus Deutschland. Martin Heidegger und seine. Zeit*, Munich and Vienna: Carl Hanser Verlag.
Schnädelbach, H. 1983. *Philosophie in Deutschland 1831–1933*. Frankfurt am Main: Suhrkamp Taschenbuch Wissenschaft.
Sebestik, J. 1998–1999. Mach et Duhem: épistemologie et histoire des sciences. *Philosophia Scientiae* 3 (2): 121–140.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

