CHAPTER 1

Mach's physical elements

Introduction

The originator of the modern realistic empiricist position was Ernst Mach (1838–1916), the Viennese physicist and psychologist whose analysis of concepts in physics, in particular space, time, energy, and mass, became famous through his book the *Science of Mechanics* (1883/1960).[1] His results on the analysis of sense perception, along with his views on the relation of psychophysics to physics, were gathered together and published in his *Analysis of Sensations* (1886/1959). Mach's physical and philosophical views were highly influential in Central Europe and beyond, on philosophers and scientists, and directly inspired Einstein's early work on the theory of relativity (Einstein 1949, p. 7).

Mach often emphasized that he was not a professional philosopher and did not seek to found a school of thought. The task of philosophy, as he saw it, was to provide a unified view of the sciences: "I make no pretension to the title of a philosopher. I only seek to adopt in physics a point of view that need not be changed immediately on glancing over into the domain of another science, for ultimately, all must form one whole" (1886/1959, p. 30).

Mach's world view of "elements" contained both empiricist and realistic features. The empiricism is well known, and often criticized, but his realistic tendencies are not. Mach's physical elements have not often received the kind of attention they deserve in a well-rounded treatment, which I tried to give in my 2003 book, *Ernst Mach's World Elements*. This is probably because of a lingering association between Mach and the logical positivists of the Vienna Circle, whom he influenced, but who took his ideas in a distinctly different direction from what Mach originally

[1] The historical roots of the position go back at least as far as Kant and Leibniz, if not before, but tracing these roots would take us too far afield.

intended. Because of this historical association with the Vienna Circle, many still believe Mach was a naïve "phenomenalist" or "verificationist" who only believed in the reality of human sensation (Blackmore 1973). In this chapter, I give a positive characterization of Mach's physical elements, based upon my previous work (Banks 2002, 2003, 2004), and show how Mach was the first to develop the overall umbrella framework of realistic empiricism. The next chapter will focus on Mach's view of psychology and the mind–body problem.

Monism, not phenomenalism

As Mach often said, the leitmotiv of his thinking was not phenomenalism but *monism*, the search for a unified, metascientific world view encompassing sensations and physical phenomena under one roof. Such a view could not be physicalistic or materialistic in the traditional sense of the "physical," i.e., positing matter in motion and nothing else, for this would leave out the reality of phenomenal experience, or make it an insoluble puzzle, as Mach's contemporary Emil du Bois-Reymond had insisted. Idealistic monism was no better since it could not do justice to the reality of the mind-independent external world by making matter a mere bundle of sensations, or in positivistic terms reducing physics to a mere catalogue of observations.

Physicists had simply ignored the problem of sensation or relegated it to psychology. Psychologists had returned the favor by ignoring physics and relying upon introspection, with all of its attendant problems. Consequently, most of the progress on the unified science front was made by those hybrid nineteenth-century sense-physiologists and psycho-physicists like Müller, Helmholtz, Fechner, Hering, Stumpf, James, and others, who struggled with this problem seriously as part of their scientific research. Mach, for his part, sought a neutral position that was neither a materialistic monism *nor* an idealistic monism, but which would allow him to study sensations of color or sound in psychophysics alongside the physical phenomena of bodies and forces, without a fundamental change of perspective and without any fundamental mental/physical distinction.

Mach's elements

Mach was a realist about human experience. An element was only a sensation when one emphasized its functional relations to the human nervous system, mental images, and psychological laws of association;

otherwise the same elements could also comprise a physical object, functionally connected with other physical events in space and time. In itself, the element was neither mental nor physical, but a simple "neutral" occurrence:

> A color is a physical object as soon as we consider its dependence for instance upon its luminous source, upon other colors, upon temperature, upon spaces and so forth. When we consider, however, its dependence upon the retina . . . it is a psychological object, a sensation. Not the subject matter but the direction of our investigation is different in the two domains . . . it is only in their functional dependence that the elements are sensations. In another functional relation they are at the same time physical objects. (1886/1959, p. 16)

A sensation like a red patch thus counts as a *real* physical event, when it is described in physical terms and in relation to other physical elements, at least in an enhanced sense of the "physical," not in the narrower sense of "physics" which covers only mind-independent objects in space and time. Red is also what Mach called a "physical quality":

> Let us analyze mental experience into its constituents. First we find those that are called *sensations* insofar as they depend upon our bodies (the eyes being open, direction of ocular axis, normal condition and stimulation of the retina and so on), but are physical *qualities* insofar as they depend on other physical features (presence of the sun, tangible bodies and so on): the green of the park, the greyness and shapes of the town hall, the resistance of the ground I tread, the grazing contact with the cyclist, and so on. (1905/1976, pp. 15–16)

Although stated in the most sober terms, Mach's position is very bold and flies in the face of 300 years of considering sensation qualities like colors to be so-called secondary qualities with no existence outside the mind and certainly no physical reality. The method Mach used to arrive at this conclusion straight off seems to me to be the method of analysis, used in ancient mathematics, which he would have known. In synthesis, the method used by Euclid, propositions are built up from simple axioms to more complex truths. In analysis, we assume the problem solved, for example the doubling of the cube, and work backwards to analyze the conditions required for the solution. In effect, Mach has simply assumed that sensations *are* physical events and passed immediately to an analysis of the conditions under which that could be true and in which they could be investigated like physical objects and events.

Russell later credited Mach and James with a conceptual breakthrough, calling it a "service to philosophy," "that what is experienced may be a part of the physical world and often is so" (Russell 1914/1984, p. 31), and that "constituents of the physical world can be immediately present to me" (p. 22). Russell also uses the word "physical" here to mean an enhanced view of the physical world that includes sensation. After his own conversion to neutral monism, Russell was effusive in his praise of Mach, calling him the "inaugurator" of the whole neutral monist "movement" (1921, p. 16) and praising him highly to another Viennese, his former student Wittgenstein.[2]

For Mach, the important features of a sensation, which it shares with physical elements generally, are its concrete individual *existence*, its quality, and the fact that sensations are *events* that change rapidly and are quickly succeeded by others. Elements are not objects or states of objects, nor are they types, abstract concepts, or relations *between* objects, at least not fundamentally. All of these other terms are derivative and defined out of elements and causal–functional relations when we strip our experience down to the bare bones. Objects do of course exist, as indeed do interactions of objects, states, and the like, but they are one and all reducible to functionally connected elements (Mach 1886/1959, pp. 6–7, 29), some of which we observe and others of which we "add in thought" (pp. 15, 43–45) by completing the function of the object, substituting unobserved elements for the gaps in observation. Again I refer the reader to Mach's passage in the *Mechanics* about a vibrating rod (1883/1960, pp. 587–588) for his view that unobserved elements are indeed necessary for physics, but only once their continuity with experience is established. And of course once continuity is established there is no reason to consider the observable/unobservable distinction as fundamental. What takes its place in Mach's monistic world view is a sort of continuous fabric of experience-reality consisting entirely of events and causal–functional relations both observed and unobserved (Mach 1905/1976, p. 361, Banks 2003, Introduction and chs. 7 and 9).

The physical reality of sensation

Human sensations were highly important to Mach, who was a major figure in the psychology of sensation and perception (Boring 1942, von Békésy

[2] Wittgenstein was gratified that Russell thought so highly of a countryman of his, but detested Mach's style of writing.

1960, Ratliff 1965, Banks 2001). He devised many ingenious experiments to measure their quality and intensity and their changes under a variety of conditions. Certainly he hoped such experiments would shed light upon the physiological basis for perception in the sense organs and the brain, but sensations had even a deeper meaning for him. For Mach, sensations were a peek, however limited, brief, and confused, at the nature of *reality*. For Mach, the blue of the sky that one sees is a real fact, as real as any in physics. Sensations are events that occur inside our brains while in certain highly complex physical states, but they do accurately manifest that reality as it truly is, and thus Mach believed sensation gave what he called a "real knowledge" of nature (Mach 1905/1976, p. 361).

Even Mach's admirers, like Paul Carus and Hans Kleinpeter, were surprised to find out just how realistic his attitude was toward human sensations. After conversing personally with Mach, they then warned against facile interpretations of the *Analysis of Sensations* that reduced Mach's position to the idealism of a Berkeley or Hume. In an 1893 article for the *Monist*, Carus reported on a meeting with Mach to clarify this issue:

> When several months ago I met Professor Mach in Prague . . . he assented to my speaking of scientific terms as abstracts . . . But when I proposed that the term "sensation" also was according to my terminology an abstract term presenting one feature of reality only and excluding other features, Professor Mach took exception to it saying that he understands by sensation reality itself. (Thiele 1978, p. 183)

Kleinpeter also gave an apt description of Mach's new realism, also in the pages of the *Monist*:

> Mach explained as the object of the naturalist's occupation "sense perceptions," a name which he chose under compulsion in lieu of a more subtle one, and which he later replaced by "elements"; for the sense in which he wished to have the word taken deviated to some extent from the customary usage. By the sound of the word we are inclined to put too much emphasis on the perceiving subject. But it was far from Mach's intention to emphasize this connection from only one point of view; on the contrary he saw at the time in sensation the material of the actual world. In this his fundamental views are essentially different from those of idealistic philosophers, Berkeley's among others. We may even call them realistic, but their realism is essentially different from so-called philosophical realism. (Kleinpeter 1906)

Mach's realistic view of sensation harkens back to a feature that has always been the animating spirit of empiricism, namely its focus on what is concretely and directly real in experience and existence. As complex and

confused as sensations doubtless are, they put us in touch with nature in a direct way, even if what they show us are the complex internal states of our own brains since that too is part of nature, for Mach. I think it is this immediate and visceral sense of *existence* that experience conveys that accounts for the perennial appeal of empiricism to Mach and many other scientists and philosophers, the present author included.

Of course this very question, of sensations being real constituents of the *physical* world, was exactly the sticking point for other critics, like Vladimir I. Lenin, who wrote a famous polemic against Mach, Avenarius, and their Russian followers such as Bogdanov: *Materialism and Empirio-Criticism* (1908/1952). Lenin's book could be considered the beginning of those positivistic and idealistic readings by Schlick, Popper, Blackmore, and others that plagued Mach's work and legacy. As one might expect, the book reads more like a political pamphlet. Lenin asked: how could the nature of the physical world of body, of atoms, of force, ever be found in sensory qualities? Qualities are *mental*; there are no qualities in *matter*, he insists. The only possible conclusion, given Lenin's stark dualism, was, predictably, that Mach was just an idealist after all, seeking to reduce real mind-independent matter to human sensations:

> Mach and Avenarius *secretly* smuggle in materialism by means of the word "element," which *supposedly* frees their theory of the one-sidedness of subjective idealism, *supposedly* permits the assumption that the mental is dependent on the retina, nerves and so forth and the assumption that the physical is independent of the human organism. In fact, of course, the trick with the word "element" is a wretched sophistry, for a materialist who reads Mach and Avenarius will immediately ask: what are the "elements"? Either the "element" is a *sensation*, as all empirio-criticists, Mach, Avenarius, Petzoldt, etc. maintain—in which case your philosophy, gentlemen, is *idealism*, vainly seeking to hide the nakedness of its solipsism under the cloak of a more "objective" terminology; or the element is not a sensation—in which case *absolutely no thought whatever* is attached to the "new" term; it is merely an empty bauble. (1908/1952, pp. 48, 49)

Lenin is captive to the very dualism that Mach and Avenarius so strenuously denied, but it is remarkable how many of his subsequent critics simply fell into line behind this plainly unfair reading. It seems to be too hard for Lenin or other interpreters to imagine, not even for the sake of argument, that a sensation is a real natural occurrence on par with events in physics, as Mach insisted, an insight which James adopted and which Russell considered "a service to philosophy." Of course the same

misreadings greeted both James's and Russell's own neutral monist works (see in particular Lovejoy 1930 and Stace 1946/1999) and some would still argue today that sensation qualities like red or blue must be mental and cannot be neutral (see Bostock 2012).

It has been pointed out to me that Mach is hard to read and understand in the original, which is true. Mach wrote in a pithy, oracular, Old-World style in which it was considered bad form to say in many words what could be said in few. He left much to the intelligence and discernment of his readers. Moreover, his expertise extended to many different departments of inquiry which he assumes his reader knows. When he uses physical examples he is assuming his reader understands physics and can read meaning into his examples. Consider one of his favorite phrases: phenomenological physics. Mach's frequent reference to so-called phenomenological or mechanism-independent laws of physics, such as the excluded perpetual motion principle, or the Carnot–Clausius version of the second law of thermodynamics, or Kirchhoff's law of black-body radiation, derived from the second law, are not understood by those philosophers who think "phenomenological" means directly observable to the senses, an unforgivably superficial corruption of a deep and beautiful physical truth about the laws of nature. Philosophers may not be aware that there are laws of physics, such as laws of conservation, the principle of least action, the principles of thermodynamics, or other postulates of experience that do not invoke underlying realizing mechanisms or realistic causation, and that this is not a philosophical view, but a fact. These laws and postulates hold of natural events whether they are directly observed or not and the distinction is between two different types of physical law; it has nothing to do with observation. In short, at risk of being overly prolix myself, Mach is not easy or readily accessible without effort, and it is thus much easier to follow and repeat secondary popular accounts with a few collected quotations, usually taken out of context, instead of reading and pondering Mach himself.

Lenin is quite correct about one thing. We are not used to thinking of the standard "physical" world of objects as constructed out of evanescent *events*. And the idea that these concrete physical events will possess concrete *qualities* does indeed make one think solely of human sensations with the qualities of color or sound, as if an idealistic reconstruction of matter into sensations were being urged. The contemporary reader might well ask, with Lenin: Why is this *not* an attempt to "mentalize" reality? What else *could* these physical qualities be, if not sensations, or proto-sensations? How could physical events in mind-independent nature

exhibit their own concrete *qualities*? Mach is attempting to revisit the basic division laid down during the scientific revolution by eminent scientists like Descartes, Galileo, Locke, Newton, and others, in their own battle against the natural "qualities" of Scholastic philosophy and earlier philosophers like Duns Scotus and Nicole Oresme in the Middle Ages. In the scientific revolution (leaving out dissenters like Leibniz and others) qualities of all sorts were permanently banished to the subjective realm of human sensation. Newton even called them "phantasms" and denied qualities any physical reality at all (in his "Rules for Reasoning in Philosophy" in the *Principia*). As Galileo and Locke had insisted, Newton also held that the *quantitative* primary qualities of matter and motion (extension, bulk, motion, number, size, shape, position, etc.) go all the way down and are simply all there is to nature, as if nature itself were a kind of erector set or a diagram in a geometry book. And given the success of natural science, in the seventeenth-century pattern of quality-less matter and motion, why should we change our view of the physical simply to find room for our sensations in our physical world view, when it makes much more sense to eliminate them?

This is certainly a powerful objection and places the burden of proof squarely on Mach and others to show exactly what the adoption of elements and their qualities would possibly add to science. We see them, but how do we know that they *are* real and not illusions like the rainbow? How could my private sensations or yours be made accessible to objective physical inquiry or measurement? This appears to me to be the main obstacle to the understanding and adoption of Mach's proposal to consider sensations—colors and all—as real physical events, again in that extended sense of "physical" that he intended to introduce.

The umbrella framework: elements and functions

First it helps to see exactly how Mach sought to change physics. There is a remarkable consistency in Mach's views on physics over the many decades from his *Conservation of Energy* (1872/1910) all the way through to the late *Knowledge and Error* (1905/1976). He ended all of these works by laying out a programmatic design for future science based upon his function-and-element methodology, saying that the job of natural science is to determine the natural variations in the elements expressed by those functions, expressing the reciprocal dependencies of the individual elements on one another, in objects, systems of objects, and human minds:

$$F(\beta,\gamma,\delta\ldots\omega) = \alpha$$
$$G(\alpha,\gamma,\delta\ldots\omega) = \beta$$
$$H(\alpha,\beta,\delta\ldots\omega) = \gamma$$
$$\psi(\alpha,\beta,\gamma,\delta,\varepsilon\ldots\omega) = 0$$

This is what I will call an *umbrella theory*, a theory schema for the construction of specific empiricist scientific theories on this model of the austere "element-and-function" methodology. An umbrella theory gives a sort of pattern to follow in constructing empirical theories of the world but it does not pronounce on the specific details. It shows what this class of theories will look like in their general features but it cannot make specific predictions; that is left to the theories themselves. So one might look at special relativity in Einstein's 1905 paper, or Heisenberg's seminal 1925 paper on quantum mechanics, as exemplars of a theory schema like the one Mach is proposing. Actually what appears to have happened is Einstein drew upon Mach's model and then Heisenberg used Einstein's theory as a schema for constructing his own theory of the atom (Heisenberg 1986).

What is very unclear at this stage is how to translate standard physics of extended bodies and motions into an event-and-function-based framework like this. Physicists do talk about events and sometimes even say that they are fundamental, but they do not actually theorize in these terms. Physical quantities are traditionally built up in dimensions of mass, length, and time and refer to the motion of extended objects like particles and fields in space and time. Various interactions between these more basic objects are what is meant by a physical event, so events are not fundamental to physics after all. There is already a kind of prior intuitive framework for physics in place before there is any talk about physical events. Laws like Newton's second law, the conservation of energy, and least action, express higher-order abstract relations of a system of particles and forces. But these do not appear to be pure causal–functional relations couched in "variations" and "counter variations" of "elementary events" of the sort that Mach posited as fundamental. The most fundamental things in physics still seem to be particulate matter and motion and fields in space and time.

Hence, I think we should regard Mach's element-and-function methodology as an attempt to actually *change* physical science rather than rationally reconstruct it as it exists (on this point, see Feyerabend 1970, 1984). Mach was never bashful about criticizing physics, with excellent results: his searching critiques of concepts in Newtonian physics (space, time, mass, energy) and nineteenth-century thermodynamics showed his

refusal to fall into line and simply recite statements of principle verbatim. He was always doing a fresh historico-critical investigation of fundamental concepts, which were the real subjects of all of his books. To Mach, science was a system of open critical inquiry, never a set of stock textbook principles and set problems to be learned by rote. Mach was also aware of important gaps in the conceptual structure of physics which he believed only an historical-philosophical analysis of physics could reveal. Long before Thomas Kuhn and the twentieth-century reaction against logical positivism led philosophers to the historico-critical method again, Mach realized that these anomalies in physics are the beginnings of new science and should not be ignored but rather brought to the forefront of inquiry.

Mach's main target for criticism was the "mechanical philosophy" of the seventeenth century, its metaphysical background, and its basic concepts. As he often said (for example 1883/1960, pp. 596–597), mechanics is not the fundamental science, but deals with objects and motions readily accessible to the senses. It comes first, historically and epistemically, but it need not go deepest. Rather the laws of mechanics and basic dimensions of mass, space, and time serve as analogies for the discovery of still deeper natural laws which need not be grounded in mechanical systems and which instead may be considered "phenomenological" principles, or "postulates of experience," grounded in natural events themselves and lacking nothing further (1883/1960, p. 599). Here is a typical passage from his 1896 *Principles of the Theory of Heat* expressing what he meant by a "phenomenological" or comparative physics, as opposed to mechanical physics:

> Physical processes present numerous analogies with purely mechanical ones. Differences of temperature and electric differences equilibrate themselves in a similar way to the differences of the position of masses. Laws which correspond to the Newtonian principle of reaction, to the law of conservation of the center of gravity, to the conservation of the quantity of motion, the principle of least action, and so on, may be set up in all physical domains. These analogies may be made to rest upon the assumption which the physicist is fond of making, namely, that all physical processes are in reality mechanical. But I have long been of the opinion that we can discover general phenomenological laws under which the mechanical ones are to be classed as special cases. Mechanics is not to serve for the explanation of these phenomenological laws but as a model in form and as an indicator in searching for them. The chief value of mechanics seems to me to lie in this. (Mach 1896/1986, pp 328–329)

Mach's powerful criticisms of mechanics convinced many of his contemporaries and those on their way up such as the young Einstein: