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# THE RISE AND FALL OF THREE FASHIONABLE EXPECTATIONS

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The primary purpose of this paper is not to describe movements which were overtaken by events but to point out some of the misunderstandings about them which were present in the recent past and which have confused the history of science and much philosophy up to the present.

In a sense it is an old tale, how the same words can mean different things to different people, quite different. In another, it is a commentary on how specialists, narrowly educated people, are like blind men who cannot help but lead each other astray, at least when the issue is more fundamental than their training has prepared them for.

From about 1880 to 1910 there was a widespread expectation among physicists that most or all of physical reality would turn out to be electromagnetic in character and that continuum physics would eventually be shown to be more fundamental than discrete or particle physics.

This expectation developed gradually, starting with Faraday's speculation about magnetic fields and "lines of force" and gained plausibility with his experimental success and Maxwell's remarkable translation of many of his ideas into mathematical form.

Hertz's discovery of "radio waves" in the late 1880's and Righi's conclusion that they vibrated and refracted in the manner of light began to suggest that perhaps everything physical reduced to some form of wave in the electromagnetic spectrum.

Lorentz's electron theory of 1892 was apparently confirmed by Thomson's discovery of electric particles smaller than atoms in 1897. The triumph of the electromagnetic world view seemed imminent, and in the eyes of many, inevitable. The age of atoms and mechanical explanation appeared over.

But there were collateral hopes or assumptions about future discovery. Most physicists were impressed by the new discipline of thermodynamics, the apparent fundamental nature and universality of its laws, and its striking application within the even newer field of physical chemistry. Wilhelm Ostwald, largely supported by Georg Helm, Pierre Duhem, and Michael Pupin, theorized that *both* discrete and continuum physics, atomism and electromagnetism, could be best explained by direct energy equations, as if energy were the ultimate physical reality.[1] Ostwald was so moved by what he called "energeticism" that in 1892 he even published a textbook in physical chemistry which contained no reference to atoms or molecules.

But Ernst Mach, the great Austrian physicist and philosopher, went beyond them all. He rejected any physical substance, whether atomic, energetic, or electromagnetic. Only sensations were real, what he called (following Fechner and Wundt) "elements" and their connections.

But there were common features of all the three forms of reductionism: electromagnetic, energetic, and phenomenalist. In positive terms they all leaned towards continuum physics, and in negative terms, opposed atomism, particle physics, and so-called "mechanism" and "mechanistic science".

One of the ironies of history is that many followers of all three movements welcomed the revolutionary work of Planck and Einstein as if refuting Newtonian or "mechanistic science" also had the effect of supporting electromagnetic, energetic, or phenomenalistic types of reductionism.

The terms "classical" and "modern" physics did *not* come in with Planck and Einstein but were in use some years ago by advocates and opponents of the new expectations and were merely continued as if the particular type of reductionism favoured had the ideas of Planck or Einstein as their natural consequence.[2] In short, the break between "classical" and "modern" physics was interpreted either to predate 1900 or to have been significantly anticipated by the respective authors of the new reductionisms.

Let us be more specific. According to Peter Galison in a recent and very interesting paper on Minkowski:

> In fact, when Minkowski refers to Einstein, it is evident that he saw Einstein as furthering the electromagnetic world picture. . . . In sum Minkowski still hoped for the completion of the electromagnetic world picture through relativity theory. Moreover, he saw his own work as completing the programme of Lorentz, Einstein, Planck, and Poincaré.[3]

In Minkowski's own words:

> Physicists suspect that one day it might be possible to explain all natural phenomena purely electrodynamically so that finally there will be no matter, nothing but electricity in the world.[4]

Galison elaborates:

> While Einstein's theory of special relativity was published in 1905, it had just begun to gain acceptance in 1910. Instead, physicists like Poincaré, Lorentz, and Abraham continued to work towards the goal of explaining all of mechanics

> purely electro-dynamically in accordance with the reductionist view which held the electron to be the fundamental building block of all matter. In fact, all three of these scientists continued to search for an electro-magnetic explanation of man until their respective deaths.[5]

Nor were the supporters of Ostwald's "energeticism" far behind. Their big obstacle was Ludwig Boltzmann and his kinetic theory of gases, especially his statistical interpretation of the second law of thermodynamics, the entropy law, which suggested that atomism and "mechanistic science" had *not* been refuted.[6]

According to Robert Millikan in his autobiography (1950):

> It is interesting to mention one other subject which I discussed with Dr. Pupin in those years, 1893-1895, namely the kinetic theory. He had become impressed with the so-called school of "energetikers", the bell-wether of which was Ostwald of Leipzig and of which I think that even Ernst Mach, Vienna's great philosopher, was a more or less convinced adherent. Pupin, too, was teaching thermodynamics and was so much impressed by that mode of physics that he once told me that he did not believe in the kinetic theory at all. This amazed me at the time, for I had great respect for his ability and it seemed to me that the evidence for the theory was overwhelming even at that time to anyone who would take the trouble to study Maxwell's epochmaking proof (1865) of the independence of the viscosity of gases from pressure or density.[7]

Ostwald and Helm, however, directly debated the issue of "energeticism" versus "atomism" with Boltzmann at Lubeck in 1895 and continued against Van't Hoff and the Vienna professor at the St. Louis World's Fair in 1904.

Millikan recalls:

> Ostwald came over from Leipzig to defend the negative of the proposition, while Van't Hoff came from Berlin to take the other side of the debate. Boltzmann was also there to support Van't Hoff. The amazing thing is that the question could be debated at all at that time, and that outstanding men like Ostwald and Helm, and even the brilliant philosopher Ernst Mach, could at that epoch be proponents of the continuum theory. By 1912 all this had changed.[8]

But if Millikan was sceptical of the "energeticist" panacea from the start, let us turn to Vienna where even as late as 1906 the following anonymously authored obituary could appear in print shortly after Boltzmann committed suicide.

> It was well-known, that the whole atomic theory was only a picture, but he (Boltzmann) held on to it as a convenient hypothesis. He thereby found himself in opposition to Ostwald, Ernst Mach and most other physicists, who for the most part are energeticists, which means that they make no special assump-

tions with respect to type of matter, but try to understand all physical processes merely with the help of concepts of pure energy. Boltzmann is the last great representative of the atomic theory in the physical world.[9]

Though Mach believed that physical reality reduced to sensations and *not* energy, it is clear from these quotations that for many physicists he was regarded as Ostwald's ally in the fight for the energeticist viewpoint. Ostwald's praise of Mach, that "he among the living and Robert Mayer among the dead had been the thinkers who had influenced him the most", Mach's criticism of Boltzmann and his statistical interpretation of the second law, and Mach's own claim that he had anticipated Ostwald concerning energeticism may have combined to encourage this falsehood that Mach was also an energeticist[10]. In fact, Mach's theory of sensory "elements" of 1886 was in its own peculiar way "atomistic", as some of his critics in psychology would later point out[11]. On the other hand, in Mach's *Warmelehre* of 1896 (which Brian McGuinness is currently bringing out in an English version) Mach did argue that whereas many changes in *chemistry* (that is, when viewed empirically and not in terms of atoms and molecules) appeared to be discontinuous, all *physical* changes were continuous, that is, the type of changes studied by physics[12]. In short, like his electromagnetic and energeticist colleagues, Mach appeared to argue for the primacy of continuum physics[13]. They might argue among themselves whether electricity, energy, or sensations were physically fundamental but they all favored a continuum approach and rejected the reality of atoms and what Boltzmann called the "indispensalbe utility" of atomistic assumptions in science.[14]

How did energeticists and Machists react to Planck's quantum theory of 1900 and Einstein's special theory of relativity of 1905? Many gradually supported both as criticisms of Newtonian physics, but in so far as Newton could be understood (or misunderstood) "empirically", that is, in Machian terms, they generally hesitated and delayed judgment. The positive side of Planck's quantum discovery disconcerted almost all physicists who learned about it (as in many ways it still does, if we may infer from the immense literature for and against the Copenhagen interpretation). As for Einstein, his physical notion of relativity was naturally confused by many Machists with epistemological relativity, as if truth itself were relative, which helped turn many of them into false or misled advocates of Einstein (a fate which Mach himself seems to have avoided).[15]

The attraction of the word "relativity" was too strong for many scientists of an idealistic persuasion to keep their wits about them. The chance to link physics with their philosophical amour propre helped blind them to Einstein's non-idealistic use of the term.

One of Mach's followers, Joseph Petzoldt, who like many "empiricists" and "positivists" refused to admit he was a subjective idealist, led the way in trying to reconcile epistemological with physical relativity[16]. In fact, he changed the title of his most popular book from *The World Problem from the Postitivistic Standpoint* (1906) to *The World Problem from the Standpoint of Relativistic Positivism* (1912) to take advantage of the developing vouge for Einstein. Indeed, Mach's few published references to Einstein were positive, though in a rather cryptic way, but once it became clear that Einstein was an epistemological realist who believed in absolute truth, the absolute nature of laws, and in the absolute constancy of light in a vacuum (but not in absolute certainty), both Mach and Petzoldt turned against him. The Mach-Planck polemics of 1908-1911 are a story in themselves. Epistemological relativity, or the notion that "all truth is relative", was *not* consistent either with Planck's conception of energy quanta or with Einstein's assumption about the absolute speed of light as a constant.[17]

## II

It was of course Planck and Einstein, the great physical "revolutionaries", who shattered all the three reductionist expectations: electromagnetism, energeticism, and phenomenalism and who helped shake reliance on continuum theory as a substitute for physical atomism. Planck and Einstein also helped re-emphasize the indirect realism about the physical world which Galileo and Newton had largely taken for granted and Descartes had openly advocated.[18]

As Thomas Kuhn has carefully documented, Planck relied heavily on Boltzmann's earlier statistical work on the kinetic theory in developing his quantum hypothesis, which among other things was a milestone on the way to the current view which treats classical or "pure" thermodynamics as less fundamental than kinetic theory[19]. As for Ostwald's energeticism, Planck opposed it as early as 1895 in his blunt paper "Against the New Energeticism" (though on different grounds than Boltzmann), but it was his quantum theory of 1900 (whether clearly viewed as "revolutionary" at that time as some historians have argued, or not as Kuhn maintains), which pointed out a physical *discontinuity* in the emission of energy, thereby contradicting Mach's 1896 claim that all physical changes were continuous.[20]

As for Mach's phenomenalism and theory of "economy", the notion that science should aim at the simplest description of the appearances, Planck openly declared his opposition in his Leiden speech of 1908[21]. Planck had difficulty at this time in distinguishing between Kant's form of phenomenalism about the physical world and the indirect realism which Planck would strongly support by the 1930's, but in any case he decisively turned against *Mach's* philosophy and methodology of science in its better known aspects.[22]

The atomic theory was the biggest battle-field of all. Einstein struck at the heart of resistance to it with his work on Brownian motion. The combination of his theoretical investigation of 1905 and Perrin's experimental support put the existence of atoms and molecules beyond reasonable doubt. Indeed, so much so that in 1908 Ostwald himself openly returned to atomism. Mach seems to have held out to the end.[23]

Had Continental scientists paid closer attention to the *differences* between Lorentz's 1892 *theory* about electrons and Thomson's *actual* discovery in 1897 it is very possible that far fewer scientists would have followed the wrong trail, an anti-atomistic "Irrweg".

Thomson's electrons did not undermine the reality of atoms, did not reduce everything to electricity, and the subsequent effort of Machists such as Ehrenhaft to discover "sub-electrons" failed.[24] Electrons remained particles, non-electrons existed, and particles would be discovered with no electric charge at all. The electro-magnetic "world picture", like energeticism and phenomenalism, if not fully refuted by 1910 began to recede in popularity. These expectations have simply not been able to explain all physical phenomena in a satisfactory manner.

## III

Perhaps the grestest irony, however, is that the defeat of these three movements, a defeat which owed so much to Planck and Einstein, has *not* been conspicuously extended to their implications. The atomic theory and "mechanistic science" are *still* rejected by many philosophers and scientists, and Einstein himself through his general theory of relativity and emphasis on field theory has strengthened the hope that all physics will eventually be united by means of a non-discrete or continuum approach.

Opposition to the *reality* of atoms currently expresses itself as *support* for the atomic theory as a mathematical formalism to describe or relate what can be sensed or measured by means of appropriate instruments. It is one thing to accept the *reality* of atoms and molecules as if they existed in an epistemologically indirect but absolute space and time; and it is another thing to allow that the atomic theory as a formalism can "describe" or "relate" what is observable or empirically measurable in a "useful" or even "indispensable" manner. The former may be called *genuine atomism* and the latter a formalistic, empirical, or pragmatic *surrogate*.

The defeat of the electromagnetic, energetic, and phenomenalist forms of reductionism and the Einstein-Perrin *proof* of the *reality* of atoms and molecules failed to banish or subordinate surrogate atomism largely because Einstein's own special theory of relativity seemed to give the impression that space and time were not only *physically* relative to the absolute speed of light but *epistemologically* relative to the consciousness of an observer, a view which Planck who was his earliest strong supporter and Einstein himself neither intended nor accepted.

If space and time were epistemologically relative to an observer, then everything in space and time including "atoms" would be relative too, presumably in a phenomenalistic or Machian sense, (Inspite of Mach's own rejection of both genuine and surrogate atomism).[25]

The Vienna Circle (which was first called the *Ernst-Mach-Verein*) failed to distinguish between physical and epistemological relativity and shunned *genuine* atomism for a positivistic surrogate. *This approach was in line with all the three fashionable expectations torpedoed (or undermined) at the beginning of the century. It is interesting that they were misusing the physical relativity theory of one who had convincingly established genuine atomism.*

Active opposition to "mechanistic science" was much more open and has continued in spite of the obvious fact that we live in an age in which machines have never been greater in number or more important in practical life. Proving the reality of atoms and the usefulness of machines has failed to shake this rearguard wishful thinking. Rather, refutation of the unconditional reliability of Newtonian science was interpreted as necessarily meaning that "mechanics" had not only lost its pre-eminence in physics but that "mechanistic science" itself had become *unconditionally false.*

Ernest Nagel comments on this exaggeration and bad logic:

> Perhaps the most serious misinterpretation consists in the widely repeated claim that modern science is no longer "mechanistic", and that both the physical theory of relativity as well as quantum theory indicate the advent of a new scientific method which acknowledges the spiritual character of reality. Now it is indeed the case that the science of *mechanics*, which was once held to be the universal science adequate for explaining all processes in nature, has lost its pre-eminence, and no physicist today believes it is possible to understand the great variety of electrical and radiational phenomena in terms of the fundamental principles of Newtonian theory. But it is one thing to say that the science of mechanics is no longer regarded as the fundamental science, and quite a different thing to claim that science is in no sense any longer "mechanistic"—that is, that it no longer seeks to discover the mechanisms and the conditions involved in the occurence of events and processes. Surely the latter is a grotesque claim, belied by every paper published in scientific journals. And just as surely, the recent recognition that mass is convertible under certain circumstances into energy, so that while the principle of conservation of energy has universal validity the principle of conservation of mass has only qualified scope, does not signify that what is loosely called "matter" has disappeared from the universe or that some sort of "mental" stuff has taken its place.[26]

## IV

But if the electromagnetic, energeticist, and phenomenalistic expectations have gone out of fashion at least in their reductionist forms, won't their implications, an opposition to mechanicism and genuine atomism, gradually decline in favor as well? Probably not in the immediate future. One must remember that the majority of well-known philosophers of science during the nineteenth and early twentieth centuries followed in the tradition of Berkeley, Hume, and Kant, and like Ernst Mach were largely phenomenalists, or as they preferred to call themselves "empiricists" or "positivists" in their philosophy of science. I am thinking of J.S. Mill, William James, Karl Pearson, J.B. Stallo, Pierre Duhem, and in spite of their "physical" language many, if not all members of the Vienna Circle. It was their influence which helped promote two out of the three reductionist expectations and long seemed compatible with the third (electromagnetism). And the influence of this tradition in philosophy is by no means dead. It lingers in the thinking of everyone who imagines that "metaphysics" is something which scientists can and should avoid, as if it were possible to do science without making assumptions about what is real. There are idealists in philosophy who accept Berkeley's notion that "to be is to be perceived", as if everything consisted of sensations, consciousness, or what he called "ideas". Such idealists have *never* sympathized with physical atomism or "mechanistic science". Phenomenalism *or subjective atomism* as it could be called is a part of that movement. It may seem strange that so many energeticists, electromagneticists, and phenomenalists should claim to reject "metaphysics" on the one hand while manifestly putting forward a theory of reality on the other, but it is often too much to ask to expect scientists or anyone for that matter to be fully consistent, to reconcile ostensible belief and actual practice.

The solution is probably to turn away from the idealistic tradition of Berkeley, Hume, and Kant and return to the *indirect realism* of the founders of modern science, Galileo and Newton, a tradition which in its epistemological aspects Planck and Einstein have done so much to restore. *The epistemological assumptions are likely to be made sound, only when the very greatest scientists exercise a greater epistemological influence than professional philosophers and philosophers of science.*

The clearest statements of where Planck and Einstein stood in epistemological matters, *their indirect realism about the physical world*, which made so many of their ideas inconsistent with fashionable philosophy and the physical expectations it encouraged, would probably be the following two remarks, both from the 1930's.

Einstein points out:

> The belief in an external world independent of the percipient subject is the foundation of all science. But since our sense-perceptions inform us only indirectly of this external world, or physical reality, it is only by speculation that it can become comprehensible to us. From this it follows that our conceptions of physical reality can never be definitive; We must always be ready to alter them, to alter, that is, the axiomatic besis of physics. . .[27]

According to Planck:

> Now, the two sentences: (1) *There is a real outer world which exists indepen-*

*dently of our act of knowing* and (2) *The real outer world is not directly knowable* form together the cardinal hinge on which the whole structure of science turns.[28]

## NOTES AND REFERENCES


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[2]Poincaré, Henri. "Hertz on Classical Mechanics", *Philosophy of Science*, edited by A. Danto and S. Morgenbesser, Cleveland, pp. 366-373, 1964, and Ludwig Boltzmann, *Populäre Schriften*, Leipzig, p. 218, 1925.

[3]Galison, Peter Louis. "Minkowski's Space-Time: From Visual Thinking to the Absolute World", *Historical Studies in the Physical Sciences*, 10, 93, 1979.

[4]*Ibid.*, p. 92.

[5]*Ibid.*

[6]Blackmore, *op. cit.*, pp. 204-216.

[7]Millikan, Robert A. *The Autobiography of Robert A. Millikan*, New York, pp. 21-22, 1950.

[8]*Ibid.*, p. 210.

[9]Anon., "Der Lebenslauf Boltzmanus", *Die Zeit*, no. 1420, Sept. 7, 1906, p. 2, col. 2.

[10]Blackmore, John. Three Autobiographical Manuscripts by Ernst Mach, *Annals of Science*, 35, p. 416, 1978.

[11]Capretta, Patrick J. *A History of Psychology*, New York, p. 90, 1967.

[12]Löwy, Heinrich. "Historisches zur Quantentheorie", *Naturwissenschaften*, 21(1933), 302-303 and Carlton Berenda Weinberg, *Mach's Empirio-Pragmatism in Physical Science*, New York, p. 52, 1937.

[13]Mach's best known contribution to physics, his study of shock waves was in the continuum tradition. There is no evidence that he used the atomic theory in his work after 1863 (when he was twenty-five), and even before then he had raised doubts about its soundness and necessity. See E. Mach, *Vorträge über Psychophysik*, edited by J. Thiele, Hamburg, 1978, which was originally published in a medical journal in 1863 and Mach's *Compendium der Mediciner*, Vienna, 1863.

[14]Boltzmann, *op. cit.*, pp. 141-157.

[15]See Mach's preface to his *The Principles of Physical Optics*, London, 1926.

[16]Joseph Petzoldt, "Das Verhältnis der Machschen Gedankenwelt zur Relativitätstheorie", Anhang zu: Ernst Mach, *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt*, 8th edition, Leipzig, 1921, pp. 490-517.

[17]Or as Planck put it in his scientific autobiography, 1950, pp,. 46-47.
"In the opening paragraph of this autobiographical sketch, I emphasized that I had always looked upon the search for the absolute as the noblest and most worthwhile task of science. The reader might consider this contradictory to my avowed interest in the Theory of Relativity. But it would be fundamentally erroneous to look at it that way. For everything that is relative presupposes the existence of something absolute. The often heard phrase "everything is relative" is both misleading and thoughtless. . . . The Theory of Relativity confers an absolute meaning on a magnitude which in classical theory has only a relative significance: the velocity of light. The velocity of light is to the theory of relativity as the elementary quantum of action is to the quantum theory; it is its absolute core."

[18]Burtt, E.A., *The Metaphysical Foundations of Madern Science*, Garden City, 1954. For a study of the different types of realism as understood in epistemology see my "On the Inverted Use of the Terms 'Realism' and 'Idealism' among Scientists and Historians of Science", *British Journal for the Phllosophy of Science*, 30, 125-134, 1979.

[19]*Van Nostrand's Scientific Encyclopaedia*, fifth edition, edited by D.M. Considine, New York, pp. 1428 and 2185, 1976, and Thomas Kuhn, *Zlack-Body Theory and the Quantum Discontinuity* 1894-1912, Oxford, 1978.

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[22]———, The Unity of the World Picture, *A Survey of Physical Theory*, Nrw York, pp. 25-26, 1960.

[23]Ernst Mach, *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt*, Leipzig, 9th edition, pp. xviii-xx, 1933.

[24]Holten, Gerald, Subelectrons, presuppositions, and the Millikan-Ehrenhaft Dispute, *Historical Studies in the Physical Sciences*, 9, 161-224, 1978.

[25]Mach, Ernst, *The Principles of Physical Optics*, London, p. viii, 1926.

[26]Nagel, Ernest, *Teleology Revisited add Other Essays in the Philosophy and History of Science*, New York, pp. 21-22, 1979.

[27]Einstein, Albert, in *James Clerk Maxwell: A Commemorative Volume* 1831-1931, Cambridge, p. 66, 1931. As Galison points out (*op. cit.*, pp. 115-118) Minkowski also leaned toward an indirect realist position in his epistemology of science, but it appears to have been more overtly Platonic than that of Einstein.

[28]Holton, Gerald, *Thematic Origins of Scientific Thought from Kepler to Einstein*, Cambridge, p. 244, 1973.