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Ernst Mach's evolutionary theory of representation

1. Introducing the problem

Mach's thinking could be characterized in terms of an *epistemological turn* in the sense of empirical epistemology, like that of the British empiricists. With Mach, Austrian philosophy takes a new orientation, by leaving aside Bolzano's logical and mathematical interests as well as Brentanos's introspective study of the human mind.
Mach came to philosophy from science. Like Bolzano, he revived the tradition of the great philosophers of the past who were also scientists. But each of them worked in different, complementary fields. Mach knew practically nothing about recent advances in logic and his mathematical knowledge did not go beyond what is necessary for the working physicist.
His goal consisted in unifying human knowledge, in closing the chasm between mind and matter, in establishing a common ground for such different disciplines as psychology, physiology and physics in order to construct a unique world picture based on science, and one compatible with common sense and explicable in evolutionary terms. Mach undetook the task of analysing the formation and the structure of the world as it is perceived and of explaining the evolution of human knowledge. He asked how did human thinking evolve from animal behaviour and reactions ? How was science formed from elementary knowledge contained in perception ? What were ultimate elements of knowledge and how could they be combined in order to obtain conceptual structures which constituted our science ? For Mach, we do not perceive colours or forms of objects ; what we really see are bodies, corporeal, material bodies in space. It is only by analyzing our perception that we arrive at its components, namely sensations.

2. *Ontology*

Mach saw a profound split between our psychical activity on the one hand, and the behaviour of unanimated objects as reflected in the difference between psychology and physics. "Psychical life seems to be a world for itself, with laws of another order", *mit Gesetzen anderer Ordnung*. On the other hand, we experience physical events as being foreign ; they could be different. The material bodies could obey different laws without that disturbing us.
Would it be possible to reduce one of these apparently fundamentally different domains and sciences to the other ? For example, can we conceive of cultural objects in terms of universal physics ? Mach resists the temptation of radical physicalism. Even a purely technical object such as Watt's steam-engine, cannot be explained in purely physical terms. We can understand a particular, individual engine in terms of physics and engineering, but in order to explain kinds of steam-engines, we must also consider their place in industrial production and in the world economy, as well as their cultural history. Even less acceptable to Mach is the physicalist explanation of the thought of a physicist. One should take into account his previous thoughts, his perceptions, his personal history including his education and eventually also the history of physics interwoven into the web of universal history – and all that is an impossible task .
Physics and psychology investigate two complementary aspects of reality. Both are legitimate and independent sciences. They both offer responses to ontological problems.

In his youth, Mach was not far from the monadological viewpoint. He considered monads (atoms) to be endowed with inner life. Nature was thought of as having two sides : a physical side and a psychological one.

> If psychical life is to be harmonized at all with the theories of physics, we are obliged, I reasoned, to conceive atoms as *feelings* (ensouled). The various dynamic phenomena of the atoms would then represent the physical processes, whilst the internal states *connected there with* would be the phenomena of psychic life.

If we accept both the atomic hypothesis and thesis of the unity of the soul, we can arrive "at a tenable monistic conception".

To destroy this kind of prejudice is the goal of Mach's mature work. There are two prejudices implied in the monadological position. One is the philosopher's realism operating with the traditional concept of substance (atom) as the permanent bearer of its properties, and with the substantial ego, the indestructible soul. The second prejudice involves the naïve attitude of every person (even that of the philosopher outside his study) who believes in a physical world independent of our minds and in the causal relationship between external objects and our sensations and perceptions. The originality of Mach's position consists in destroying the twofold prejudice and at the same time in preserving the naïve attitude of the ordinary man.

First, Mach asks, how do we know about substances ? Have we the right to conclude the existence a permanent source of our perceptions from the fact that we can have different perceptions of the same object ? Must there be an undestructible substratum behind sensible data ? According to Mach, the permanence of a thing does not imply its eternity or indestructibility. We have no experience of absolute permanence ; our experience does not go further than mere relative constancy. And above all, we have no access to any mysterious source behind our perceptions ; they are all what we have.

If the philosophical prejudice about abiding substances has to be rightly rejected, the natural attitude has to be explained. The latter is for Mach the fruit of the biological evolution of the human species. The identification of recurring, more or less permanent complexes of properties had been of vital importance in the struggle for survival. The need to schematize the extremely complex world where man was both prey and hunter led to the idea of something permanent producing the manifold of sensory experiences. The realistic fiction of objects hidden behind perceptions can be useful. In *The Analysis of Sensations*, Mach considers a conceptual word such as "matter" to be a "highly natural, unconsciously constructed mental symbol for a complex of sensuous elements". The same also holds for the thesis of "the artificial hypothetical atoms and molecules of chemistry" : it has only the value of "economical symbolization of the world of experience" . Such a hypothesis may serve as a mathematical model to describe certain experiences. The philosopher, however, must explain the origin of such fictions and the limits of their use. Hence Mach's *phenomenism.* Although physics operates with independent external objects and psychology operates with inner mental states, both fields deal with one and the same kind of reality, the only one to which we have direct access and which is all what is really given, namely sensations, *Empfindungen*. "There is no rift between the psychical and the physical, no *within* and *without*, no *sensation* to which an outward thing corresponds. There is but *one kind of elements*" .

The world is a web of sensations, or to use, with Mach, a more appropriate word (because not associated with subjectivist philosophy), a web of *elements*, i.e. colours, sounds, pressions, odours, pains etc., and also of spatial and temporal elements. External objects, living beings,

other people, and also myself, my "soul" or "organ of consciousness", *mein Bewusstseinorgan*, are nothing else but more or less stable functional complexes of such elements. Neither the naïve, non-philosophical realist, nor the scientist looses anything. The world remains as colourful and tasteful as before, just as painful with some pleasures. Only the superfluous colourless and tasteless fictitious entities are withdrawn from this picture.
Nevertheless, such an attitude demands an authentic conversion, a renunciation of the mental and linguistic habits which the human species has developped since its origins. The proud *ego* of modern rationalistic philosophy, the Archimedean point of all certainty, has became a provisional combination of sensations, volitions, thoughts and feelings which migrate and join other combinations of elements endowed with a *Bewusstseinsorgan* and a *Vorstellungsorgan* (organ of representation). Mach recalls Lichtenberg's aphorism according to which we should not say *I think*, but *it thinks*, and adds that the ego cannot be saved, *das Ich ist unrettbar*. Personal mortality is but a dream. Does not everyday experience teach that parts of ourselves die long before our death ? On the other hand, however, being composed of the same elements as other complexes of elements, and having no sharp boundaries, "the ego can be so extended as to ultimately embrace the entire world" .
The equally fictitious idea of causality – understood as real flowing from one body to another one – has to be explained in terms of functional dependence open to formulation in quantitative terms. Reformulated in this way, understanding causality continues to provide the impetus of all scientific research. Physical laws express what is abiding in nature : not the elements themselves, but the links between them.

3. The theory of representation

Mach sets out to determine the origin and the cognitive function of our representations. "All science has for its aim the *representation of facts in thought*, either for *practical* ends, or for removing *intellectual* discomfort" , he wrote. Upon other occasions, he insists on the adaptation of thought to facts, without further justifying transfering a concept borrowed from biology to epistemology.
As we have seen, sensations are the ultimate elements of our experience, the simplest elements of the world forming the basis of our physical concepts. Sensations alone, however, do not suffice to produce scientific knowledge. Without memory, our life would be a kaleidoscope, a sequence of unrelated mental states. It is memory that transforms sensations into representations, *Vorstellungen*, defined by Mach as "traces in the memory of earlier experiences which co-determine and weave further new complexes of sensations" . Mach does not acknowledge sharp boundaries between different sorts of mental acts; a continuous transition leads from sensations to intuitive representations, to ideas, ordinary concepts and eventually scientific concepts. Sensations are more vivid, stronger ; representations appear and disappear rapidly, combining into larger complexes or varying according to individual phantasies.
While subjective representations respond to individual needs, concepts meet the intellectual needs of the human species. Like other representations, they have a physiological basis in sensory elements. They are produced by a similar configuration of sensations which create strong associations of representations directed towards biologically relevant behavior. Even animals have "seeds of concepts", even if they do not have the corresponding linguistic term at their disposal. Concepts are that element of human experience under which objets to which we react in the same manner fall. The difference between the behaviour of animals or prehistoric humans on

one hand, and civilized people on the other, consists only in the fact that the latter are able to perform a variety of testing and checking activities and to organise concepts into systems of hypotheses and theories.

The adaptation of new facts finds its expression in the formation of judgments. Judgments consist primarily in the broadening, "supplementing or amendment of the deficiencies of a sensuous percept" by other sensuous percepts. Stored in the memory, they become, according to Locke's terminology, "intuitive knowledge", the spontaneous recollection of facts. Two principles are at work in the further refinement of judgments : that of the broad generalization and continuity and that of sufficient differentiation.

Both contribute to selecting pertinent elements of perception. If the progressive mental adaptation embraces a great number of facts, the discovery of new facts, possibly incompatible with the earlier ones, can lead to new conscious and purposive adaptation. Such is the beginning of scientific investigation that involves comparison and differentiation of a number of instances falling into the same category. We examine the influence of varying factors in repeated experiences and, having formed abstract concepts, we are able to solve the given problem.

We name concepts and accompany them with images. A word yields nothing but an impulse to perform a sensory operation and this is the mark of the concept. (Mach also counts as sensory operations the enumeration of the number of angles in the case of the concept of "heptagone", or the identifications of factors when considering the concept "square number"). But "the concept is never a *finished* percept" (p. 162, for the operation adds a new sensuous element not present earlier. The concept is "an instruction to *test* a given representation with respect to certain properties or to *produce* a representation having determinate properties" . As an example, let us take the conic sections. I cannot directly see that the ellipse, parabola, hyperbola are subsumed under that concept ; but I can discover the fact by cutting a cone and by constructing the equation for conics. Is the latter operation also a sensory one ? As the examples have shown, Mach considerably extends the notion of sensory operation ; for him, it included any operation involving counting or manipulation of signs. Closer to sensory operations are of course those performed by physicists and chemists.

The decisive moment in concept formation is *abstraction*, i. e. the separation and selection of sensory elements and complexes (form, colour, material aspects, use and nature of the object) in accordance with our biological needs. Thus we learn to consider biologically relevant aspects of an experience separately. But the abstraction in question is not only a process of taking away, a negative operation, a refraining from attending to the sensuous elements which accompany the abstracted entity in the given complex ; it is at the same time an adding process : "on the other hand, it is turned *toward* other and *new* sensuous elements" .

The step from ordinary concepts to scientific ones consists in the intention. It is the intentional formation of concepts and their combinations that marks the beginning of scientific concepts.

In scientific concepts the intellectual domination of nature reaches its peak. According to Mach, a scientific concept is "a precise and definite *reaction-activity*, which enriches the fact with new sensuous elements", more precisely "the consciousness of reactions that we expect from the class of objects designated by the concept-word" . Hence, a scientific concept is a mental complex more or less permanently connecting memories and expectations related to selected aspects of the behaviour of an object. Let us take the concept of a chemical element, for example of natrium. It is a sum of expectations concerning atomic weight obtained by measurement, colour, solubility in water etc., and similarly with mathematical, physical or biological concepts like "circle", "intensity of current" or "whale". To have a concept means to be able to submit it at any time to testing in order to obtain the expected reactions. A concept can always be traced back to intuitive

elements, but such a link can be indirect or even only potential. The result of a physical investigation "is based upon an almost unending series of simple observations (sensations)", because we must also take adjusting the experimental apparatus into account. In this way, the concept appears simultaneously as a condensation of previous experiences and as an instruction to test and to produce specific representations or sensations, a sequence of operations. Eventually, language contributes to stabilize the concepts and to form a conceptual system, a scientific theory.

The following schema sums up Mach's theory of mental objects (*psychologische Gebilde*) :

1) sensory experiences, sensations,
2) intuitive representations obtained by recollecting past experiences,
3) typical representations (even animals may have them; they are the "seeds of concepts"),
4) everyday empirical concepts obtained by abstraction from intuitive and typical representations.
5) scientific concepts.

4. Scientific knowledge

For Mach, unity of the physical and psychological dimensions is fundamental.
Mathematics plays a secondary role in his theory of science which aims principally to connect sensory experiences to theoretical concepts. An excellent physicist and historian of physics, Mach was not a very good mathematician. Speaking of mathematics, he considers it simply an auxiliary instrument, not as a means to express the structure of physical theory. "All auxiliary conceptions, laws and formulas, are but quantitative norms, regulating my sensory representation of the facts. The latter is the *end*, the former are the *means*."
As we have seen, theoretical concepts transcend immediate experience. Mach explains the progressive distancing of theoretical concepts by a natural tendency inherent in our thoughts which

> are spontaneously impelled to *complete* all incompletely observed facts.[…] The impulse in a certain measure *enriches* the single fact. Through it the latter is *more* to us. By this impulse we have always a *larger* portion of nature in our field of vision (p. 171).

Although the world is constructed from sensory elements, our knowledge often complements them by formulating hypotheses which go far beyond our experience, extending the field of knowledge by extrapolation. We can mentally add elements which are not only absent from the sensory field, but which cannot even come into it. We can e.g. imagine the moon as an inert heavy mass without any possibility of touching it. Another famous example is Mach's principle which appeals to the action of *all* celestial bodies in order to explain the law of inertia.
It is therefore necessary to make a sharp distinction between what we see and what we mentally supply. Only this distinction enables us to see old theories as obstacles for new discoveries. Mach cites many examples : the phenomena of conduction and exchange of heat, which led Black to the discovery of specific heat. But the same idea – the constant quantity of heat-substance – kept Black from realizing that heat can also be produced, as everybody knows, by friction. Huygens' fundamental discovery of the undulatory theory of light prevented him at the same time from rightly grasping the phenomenon of polarization, which he himself discovered. The preconceived

idea of fluids acting at distance on conductors stood in the way of the discovery of specific inductive capacity ; only Faraday, a non-academic, could overcome the theoretical prejudices of other scientists. Mach insists that theories are only auxiliary instruments for definite purposes. They have no absolute value.

Constancy plays a major role in Mach's conception. Our expectations are based on it. Things (complexes of elements) are relatively constant and we have a natural tendency to think that they are always present, whether we perceive them or not. Chemical elements also appear unconditionally constant. We expect constant replies to our questioning in the entire realms of facts covering, for example, electricity, magnetism, light, heat. The notion of "electric body", for instance, means for us expectations of definite groups of facts. On the other hand, the unity of nature does not permit us to isolate one specific fact or group of facts : "there is no such thing as a specific *electrical* fact […] all physical facts are made up, in ultimate analysis, of the same sensuous elements (colors, pressures, spaces, times)" (p. 168). Completing our observation, we speak of the constancy of celestial bodies, and even of the whole past and future, the entire passage of time.

Such projections are not founded, for unconditioned constancy of things does not exist. Here, Mach steps out of his world of ever-changing elements-sensation to reach a *structural* point of view :

"There is but one sort of constancy, which embraces all forms, namely, constancy of connection (or of relation)" (p. 169). This constancy of relations is precisely what physical laws express. If the constancy of thought consists in the impulse to complete observed facts, physics formulates quantitative norms regulating our spontaneously flowing thoughts. History of physics can be characterized by the increasing degrees of constancy. "Whenever we have a special interest in the representation of facts, we endeavor to support and corroborate ideas of lesser constancy by ideas of greater constancy or to replace them by the latter" (p. 172). Analogy with already obtained results in mechanics guided Newton to conceive of the planets as projectiles. Similarly, Huygens (and many others) were led by the analogy of sound in optics. Because since the XVIIth century mechanics has become the paradigm for all natural science, the scientist have sought "to conceive electrical, optical, and thermal processes as *mechanical* processes".

> We naturally prefer, as the foundation of this process, the strongest and most thoroughly tested thoughts, and these are given to us by our much exercised mechanical functions, which we may test anew at any moment without many or cumbersome appliances. Hence the authority of mechanical explanations, especially those by pressure and impact **.**

Only one science can yield greater certainty, namely mathematics, because mathematical thought must conform its own norms even if it grows from extraneous impulses. Mathematics invariably carries "most of the material for experimenting about with it", as if internal mathematical experience imposed its norms to elements received from outside. A mathematical formula in physics, for example the sine law of refraction, "is a kind of geometrical model which simply ***i****mitates in form* the refraction of light and *takes its place* in our mind" (p. 187).

For Mach, geometrical space is a structure both of space-elements and of physical elements : "it is by no means made up wholly of the system of space-*sensations* (of the senses of sight and touch), but consists rather of a large body of *physical* observations, having the space-sensations as their point of departure" (p. 177). The most important of such observations concerns the behaviour of rigid bodies and the notion of superposition yielding congruence for measuring lengths and angles. "When we are *compelled* to imagine an isosceles triangle as having equal

angles at its base, our compulsion is due to the remembrance of powerful past experiences". Thus the geometer goes far beyond the space given by sight and touch which is not homogeneous. The Euclidian method, too, presupposes "abundant geometrical experiences". "It serves to protect us from the possible errors which we have acquired" (p. 177n.). Mach does not attribute particular importance to proofs and to the deductive structure of mathematics.

"The *memory* of a given experience can reveal to the mind features which in the original observation escaped unnoticed". Such is the power of geometrical imagination, which holds also for pure mathematics, even for arithmetics. "Even the theory of numbers must be looked at in some such manner; its fundamental propositions can hardly be viewed as entirely independent of physical experience" (p. 178). And Mach repeats almost literally Bolzano's remark, according to which the certainty of mathematics comes from the fact that its results "can very easily be tested on intuitions and experiences" :

> The cogency of geometry (and of all mathematics) is due", not to "some select and special kind of cognition, but only to the fact that the empirical material which is at its base is particularly convenient and handy, has been put to the test an untold number of times, and can be subjected again at any moment to the same tests (p. 178).

The same also holds for time : "When a physicist wishes to determine a period of time, he applies, as his instrument of measurement, *identical* processes or processes *assumed to be identical,* such as vibrations of a pendulum, the rotation of the earth etc." (p 179). The result of his measurement is a number.

5. Conclusion

Mach wants to reconstruct the "natural world" of human experience , purified of theological and philosophical prejudices. At the same time, he tries to explain common sense realism in terms of permanence of sensory complexes and the biological response of organisms to the challenges presented by their environment. But, unlike the phenomenologists, Mach's "natural world", is not in opposition to the abstract world of modern science whose paradigm is mathematical physics. For Mach, the world of science, though organized according to specific human needs, grows spontaneously out of original experiences.

Mach's thinking to a large extent anticipates further developments in the empiricistic, pragmatist and evolutionist trends of the XXth century. His legacy, together with that of Bolzano, merged into the powerful current of analytical philosophy, represented in the first half of the XXth century by the Vienna Circle and, as regards Bolzano, also by the Polish school.

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. Nevertheless, according to Martin Kusch, Wundt and almost all contemporaries of Mach took him for a reductionist, a physicalist.

. *Beiträge zur Analyse der Empfindungen* (Prag, 1886); I quote the American translation, (La Salle, 1897) *Contributions to the Analysis of Sensations*, p. 183.

. *Ibid. p.* 152-153. Mach continues protesting against all materialistic and physicalistic attempts to explain mental phenomena by material processes : "Still less, therefore, should the monstrous idea ever enter our heads of employing atoms to explain psychical processes ; seeing that atoms are but the symbols of certain peculiar complexes of sensuous elements which we meet with the narrow domain of *physics*."

. *The Analysis of Sensations*, p. 153.

. *Ibid.*, p. 10.

. *The Analysis of Sensations*, p. 153. By "intellectual discomfort", Mach means logical shortcomings such as incompleteness, contradictions and similar.

. "Erinnerungsspuren älterer Empfindungserlebnisse, die neue Empfindungskomplexe mitbestimmen und weiterspinnen", *Erkenntnis und Irrtum*, (Leipzig, 1905), p. 20.

. *The Analysis of Sensations*, p. 157.
. *Die Prinzipien der Wärmelehre*, (2nd ed., Leipzig, 1900) p. 419.
. *Ibid*., p. 165.
. *Ibid*., p. 162 ; "…das an das Wort gebundene Bewusstsein von den Reaktionen, die man von der bezeichneten Klasse von Objekten erwartet", *Wärmelehre*, p. 131.
. *The Analysis of Sensations*, p. 156. All following Mach's quotations are from this work.
. But Mach reminds us that "pressure and impact are by no means simpler phenomena than are for example the phenomena of gravitation. The contention that in physics everything can be reduced to the motion of smallest particles is, at best, but an improper draft on the future". *The Analysis of Sensations*, p. 184n.
. *Beiträge zu einer begründeteren Darstellung der Mathematik* (Prag, 1810), p. 150.
. The natural world of human experience (Husserl's *Lebenswelt*) should not be confused with the world of nature.