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Giorgio Israel, *Meccanicismo. Trionfi e miserie della visione meccanica del mondo*, Zanichelli, Bologna 2015 pp. xiv+322, ISBN 978-88-08-52129-3; 28€.

This is Giorgio's Israel last book, appeared a few weeks after his untimely death, in September 2015. For many reasons, it can be considered as his intellectual legacy, since it comes back, in a new and organic way, to many of the research topics he devoted his life to, by publishing, among many others, also several papers for *Historia Mathematica*, including one (co-authored with M. Menghini) appeared in vol. 25/4, 1998, devoted to Poincaré's and Enriques's opposite views on qualitative analysis, a theme also dealt with in this book (pp. 117-122).

The title of the book is clear enough to indicate his main purpose, but it does not explicitly display the richness of the survey Israel offers to the reader. Speaking of mechanism is, for him, a way to refer to a quite large complex of philosophical and scientific views, variously connected with the basic ideas that "any phenomenon is nothing but the result of the motion of bodies, or can, anyway, be described or explained in these terms", and that "any part of nature is tantamount to a machine" (p. xii; here and later, the English translation from Italian is mines). This quick and largely insufficient characterisation (explicitly so intended by Israel himself) is already enough to make clear the theoretical and historical richness of the topic, since it openly discloses a number of ambiguities coming together with the use of the term 'mechanism' in history and historiography of science and philosophy.

One of them concerns the way machines and bodies, as well as the motion of the latter are conceived. Another comes with the extension attributed to the universal quantifier in 'any phenomenon', or with the comprehensiveness of the term 'nature': is the mechanist view necessarily associated with a dualist conception separating both mind from body (or "physical world" from "subjectivity": cf. § 6.1) and the unanimated sphere from the biological and/or social one, or does it extend to the opposite fronts of these dichotomies? The book quite exhaustively deals with both these ambiguities and with many others, so making its enquiry branch off to determinism, materialism, causalism, various forms of reductionism, and give, in particular, considerable attention to the role assigned to mathematics in different variants of these views, and to a number of its developments, especially (but not only) to applicative ones.

This makes the book an essay in history of ideas, without making it depart from history of science, including mathematics, in its more specific and technical aspects. More than that, one of its main purposes seems to be methodological in nature: it consists in promoting an integrated approach in which history of science, philosophy and culture do not separate to each other, and, rather, not only cooperate, but incorporate themselves so as to reconstruct a number of intellectual events in all their actual ramifications and effective unity. The point is explicitly made in the introduction: the only promising perspective for historical science studies, in the critical present conjuncture, is that of "an historiography of science with philosophical grounds, which centers on the dynamic of ideas" (p. ix).

After the introduction, the book includes seven chapters in a partial chronological order, as it were: on a basic chronological structure, several coming and going are grafted, which allow the reader to consider some themes, already dealt with in earlier sections, in a new framework or under different respects, in relations with other ones.

First comes a chapter entirely devoted to Descartes: his mechanistic conception of the physical world; his idea that all its science is mathematical in nature; his conception of geometry; his radical dualism. A large part of this chapter is devoted to argue that *La Géométrie* is to be read as a mature realisation of the project advanced in the *Regulae ad directionem ingenii*. This results in a quite original account, opposite to two very common views: that which identifies the hard core of Descartes's geometry in his algebraic formalism,

with base on the assumption that geometrical curves are, for him, nothing but loci of algebraic equations; that which, though defending the priority of constructive geometry in Descartes's conception and taking the algebraic formalism as a tool for working on constructively identified objects, insists on some radical changes in Descartes's program occurred between his youthful project of *Mathesis universalis* and the plan of *La Géométrie*. Against both these views, Israel sees the distinctive aspect of Descartes's geometry in its adherence to his analytic method, whose quite peculiar character depends on its being both deductive and constructive, and so conceiving algebra as an universal language to be used for sake of generality, but submitting it to continuous and unbroken constructions providing both the objects of enquiry and the solution of problems. In Israel's own view, any alternative account fails in grasping the intimate link between Descartes's mathematics and his philosophy.

The second chapter is mainly concerned with the science and the conception of science of the Enlightenment, in particular to their ambiguous links with Newton's achievement and its reductionist legacy, Locke's sensualism, and Descartes's mechanism and dualism, and to the consequent program of a "metaphysic of science". The following quotation, drawn from the end of § 2.1 (chiefly devoted to d'Alembert's philosophical views) provides a quite clear illustration of focus of the chapter (pp. 64-65):

We have insisted on the distance of Cartesian metaphysics from eighteenth-century metaphysics of science. The Century of Enlightenment sharply rejects the Cartesian idea of a linear and causal order. But, in fact, this is rejected only in ontological terms. This idea reappears indeed in the theory of knowledge, and the vector of its coming back is just the hard core of the philosophy of Enlightenment: the analytic spirit and the idea of its universal pervasiveness. It is a singular paradox that the analytic spirit expresses in the clearest way what, in the same time, divides and unifies Descartes's views and the eighteenth-century scientific culture.

The chapter also includes a discussion of the atomism vs. continuity tension in the foundation of infinitesimal calculus and its applications to mechanics—with specific attention on (d'Alembert's treatment of) the equation of a vibrating string, Laplace's equation of potential, and Fourier's equation of heat diffusion—, and of the origins of the principle of least action, and the different forms of finalism which it comes with, in Maupertuis's and Euler's treatment, respectively, as opposed to the causalist conception to which Lagrange and Hamilton will later accommodate it.

The third chapter deals with determinism and mathematics. The topic is considered on a quite large temporal spectrum, starting from Laplace's approach up to the recent theories of deterministic chaos, passing, of course, through Poincaré's basic results on the subject. In this chapter, an important theme, which will become crucial in the last part of the book, is nicely anticipated: that of the role of mathematical models in science and their relation with the (physical, social or physiological) reality they stand variously for. The question considered in this chapter is that of the relation between a deterministic or anti-deterministic conception of the physical world and some important mathematical results concerned with the solution of ordinary differential equations, as the theorem of existence and uniqueness, the existence of singular solutions, and the height sensitivity to initial conditions of some dynamical systems. Israel emphasizes the crucial opposition between the global nature of any deterministic view on the physical world and the local character of the theorem of existence and uniqueness, which makes impossible to base on the latter any coherent argument in favour of the former. But he also insists on the analogous impossibility to base on the mathematical phenomenon of deterministic chaos any argument in favour of the fact that the physical reality is highly sensitive to initial conditions (so that a today butterfly's flap can cause a cyclone in four months). The question is then whether these mathematical results have some sort of ontological import for the physical world and/or epistemological import for our science of it.

Israel does not limit himself to the obvious remark that these results can only relate to a physical phenomenon through the models of it they are pertinent to. He also raises a quite crucial and much more relevant question: whether “deterministic chaos entails a principled impossibility of reducing the gap between forecasting and effective reality of a phenomenon” (p. 138). If it were so, any form of objectivism would be under a serious attack, since, “if a forecast were not perfectible (if not perfect, as nobody never required), if the objective reality were not only exactly indescribable (as we already knew), but were no more the parameter of our representations that allow us to verify the process of refinement of our knowledge, what else might our science become, if not a description of itself?” If it were so, “it would no more be an image of the reality, but an imagine of our imagines” (p. 139).

The fourth chapter is devoted to the continuum vs. discrete opposition, regarding both space and time. The chapter begins by coming back to Zeno’s paradoxes, conceived of as proofs “that the geometrical continuum of elementary intuition is an indivisible which does not lend itself to a quantitative treatment, and that geometrical-quantitative description of motion leads to insurmountable aporias” (p. 142). More than that, according to Israel, “the sense of [Zeno’s] paradoxes is deeper and more general: it affects the conception of continuum and the relations between geometry and arithmetic” (*ibidem*). This makes he sees in them the essential reason of the “divorce of arithmetic and geometry” realized in Greek mathematics: a divorce which “modern mathematics” has overcome “in pragmatic terms, but definitively not in conceptual ones” (p. 146). Indeed, contrarily to what it is claimed in many text-books, the absence of any “rigorous definition of what is a point” makes impossible to prove the existence of a bijection between “the set of real numbers and [the points on] the geometrical line” (pp. 146-147). The basic idea is well-known, and has been, for example, strongly advocated by Thom in several occasions: the geometrical continuum is a primordial entity and cannot but be imperfectly imitated in arithmetic terms. Israel illustrates the matter through two examples: the use of the ambiguous (and finally non-rigorous) notion of material point in mechanics, from Newton to Lagrange and Levi-Civita; and the dispute on hereditary mechanics — a theory, based on integro-differential equations, intended to account for phenomena where the future is determined not only by the present, as in usual deterministic systems, but by all the past —, firstly introduced by Picard, Boltzman and, overall Volterra, and strongly opposed by Painlevé.

The fifth chapter comes back to the notions of objectivity and objectivism. It begins by observing that the Scientific Revolution, though admitting “the impossibility of fully go through the infinite [...] [and, then] to construct an univocal and objective representation of the universe [...], does not stop face to this limit, but makes of it the motor of its omnipotence”, since it is just because of “an unbridgeable separation between human knowledge and reality, which is possible to gain knowledge with basis in truth” (p. 178). The point is illustrated by a discussion of Nicholas of Cusa’s dualism between empirical and absolute truth, his (Platonic) view that only mathematics can offers to us a “conceptual representation of the ideal sphere” (p. 180), and the ways these ideas resurface in Descartes and Galileo. The chapter continues, then, with an extensive discussion of the ideal of scientific omnipotence and objectivity that takes form from the Renaissance (with particular attention to Bruno) to the early-modern age. The basic idea is that “human being, which in Copernican universe seems to have lost a sort of centrality [namely ontological centrality], gains a new sort of it”, given by the capacity of knowledge, namely epistemic centrality.

The sixth chapter enlarges the attention beyond the “unanimated world” (p. 193), toward, psychological, social and biological ones. It begins by considering Turgot’s and Quesnay’s projects of a science of society as a base of a rational government of it, and the way they evolved in Condorcet’s views, within the more general contest of the movement of *Idéologues*, up to the program of mathematisation of social sciences. Israel observes that the

first step in this direction comes in fact from 1760 Daniel Bernoulli's memoir (presented to the Paris Academy of Sciences) on the advantages of inoculation to prevent smallpox. In this memoir, the question was studied through probabilistic methods, which, though provoking d'Alembert's reaction, opened the route for a probabilistic approach to social phenomena. Probability was not, however, the only mathematical tool that came to be used for studying these phenomena. The birth of mathematical economy, beginning with the naïve attempt by Canard, up to the much more sophisticated works of Cournot and Walras, provide the example of the use, for this purpose, of analytical methods inspired by rational mechanics. A strong reaction turned against these first attempts, inspired by romanticist conceptions. To illustrate it, Israel considers Cauchy's attitude, restricting mathematical sciences within "their own domain" (p. 215), the Poisson vs. Poincaré quarrel on the use of probability in "moral questions" (*ibidem*), and the general hostility against Walras's theory, expressed, among others, by Poincaré himself. Starting from the second decade of 20<sup>th</sup>-century, this reaction loses its force and mathematical applied to non-physical phenomena runs rampant, by giving rise to a large numbers of mathematical models for these phenomena. More than considering a few examples (which he merely lists quite quickly for their being all well-known, by mentioning, among others, the models for population dynamics mathematical epidemiology, population genetics, human physiology and pathology, economic equilibrium and many other applications of game theory), Israel insists on the reasons of this new pervasive trend. The basic one is the "crisis of classical reductionism", and the "progressive decline of the confidence in the existence of great laws of nature", which did just result in the "withdrawal towards the more modest and effective aim of construction of models": mathematical science of non-physical phenomena flourished just insofar as the ideal of scientific explanation and interpretation run out, in favour of the idea that the aim science is rather that of offering models to be "evaluated on the base of criteria of efficacy rather than truth" (pp. 220-221). This discussion gives room for a number of further considerations concerned with the theory of complexity, von Neumann's (essentially unsuccessful) searching for a new mathematics for non-physical application, and the worthlessness of any third way between the two unsuitable ideals of determinism and probabilism as general perspectives apt to govern an application of traditional mathematics to non-physical facts.

The last and seventh chapter acts as a conclusion. It consists of a passionate plea for a new humanism in which science and literature cooperate, against the present versions of mechanism and reductionism, as much triumphant as devoid of any rational justification, and blind to any human concern.

As said above, the book can (and should) be considered as Israel's intellectual legacy. If the first six chapter present this legacy under the form of a revival of his quire rich and comprehensive historiographical contributions to a rigorous, as exhaustive as possible, and technically and culturally deeply competent and informed approach to our scientific past, the last chapter presents it under the form of a moral manifest condensing much of his intellectual struggles in favour of a scientific practice more attentive to human needs, and of a scientific community more open to human capabilities and more in line with human freedom.

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