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On the borderline between Science and Philosophy: A debate on determinism in France around 1880

Stefano Bordoni

Bologna University, Department of Pharmacy and Biotechnology, Via Dei Mille 39, 47921 Rimini, Italy

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ABSTRACT

In the second half of the nineteenth century, a new interest in explosive chemical reactions, sudden release of energy in living beings, physical instabilities, and bifurcations in the solutions of differential equations drew the attention of some scholars. New concepts like triggering actions and guiding principles also emerged. Mathematicians, physicists, physiologists, and philosophers were attracted by this kind of phenomena since they raised a question about the actual existence of a strict determinism in science. In 1878 the mathematical physicist Joseph Boussinesq pointed out a structural analogy among physical instabilities, some essential features of living beings, and singular solutions of differential equations. These developments revived long-lasting philosophical debates on the problematic link between deterministic physical laws and free will. We find in Boussinesq an original and almost isolated attempt to merge mathematical, physical, biological, and philosophical issues into a complex intellectual framework. In the last decades, some philosophers of science rediscovered the connection between physical instabilities and determinism, both in the context of chaos theory, and in the debates on the Norton dome. I put forward a consistent historical reconstruction of the main issues and characters involved.

In the second half of the nineteenth century, mathematicians, physicists, physicians, and philosophers were involved in debates on the complex relationship between physical and chemical instabilities, sudden release of energy in physiological processes, the questionable existence of human free will, and the determinism of scientific laws. The French mathematician Joseph Boussinesq played an important role in that process of cross-fertilisation among different disciplines: he put forward an original research programme, where different traditions of research really converged. We find the integration among mathematical researches, where singular solutions of differential equations were involved, researches in physiology, where concepts like "*Auslösung*" and "*principe directeur*" had recently emerged, and physical sciences, were transformations of energy in general, and concepts like "*trigger-work*" and "*travail décrochant*" were at stake. Boussinesq managed to offer a sophisticated and unified framework for new questions and new concepts, but his research programme faded into the background after some scientific and philosophical debates. Only after a century, some issues re-emerged in the contexts of chaos theory and philosophy of science.

The present paper puts forward a new historical reconstruction of that intellectual landscape: it aims to cast light on the network of concepts and attitudes that crossed the fields of mathematics, physics, philosophy, and life sciences. The first section is devoted to physicists and physicians who attempted to shed light on explosive processes in inanimate matter, and energy thresholds in living beings. The second section enquires into the mathematical and physical interpretations of differential equations. The third deals with Boussinesq's original integration between mathematics, science, and philosophy. In the fourth, I report on subsequent debates that involved mathematicians and scientists. In the last section I confine myself to some remarks on later philosophical debates and recent historical reconstructions.

E-mail addresses: stefano.bordoni@gmail.com, stefano.bordoni2@unibo.it.

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1. Triggering actions in physics and life sciences

In 1842 Robert Mayer stressed the two essential features of forces [Kräfte] or causes [Ursachen].[1] Firstly, they could not be destroyed, and second, they could be transformed into each other. Every cause produced a corresponding effect [Wirkung], and the effect had to equal the cause. Two years later, in a letter he sent to the physician and psychiatrist Wilhelm Griesinger, he stressed how questionable the meaning of the words "cause, effect, and transformation" really was. In the field of mental processes, could we say that "the cerebral activity" is the "cause" of the book a scholar is writing? It would be definitely pointless to say "the cause, namely the cerebral activity, transforms itself into the effect, namely the book". In the field of physical and chemical processes, the transformation of a cause into an effect was not less problematic. If a spark triggered off an explosion, might we say that the former is the cause of the latter? In this case, we cannot find an equality between cause and effect: how could the two laws Mayer himself had put forward two years before, namely the conservation of causes and their transformation into effects, be satisfied? (Mayer, 1842, pp. 4–6 and 9; Mayer, 1844, pp. 98 and 100–102).

In 1862, in a letter to the Scottish classical scholar Lewis Campbell, James Clerk Maxwell hinted at the problem of "action and reaction between body and soul". He remarked that "when a man pulls a trigger it is the gun powder that projects the bullet", and "when a pointsman shunts a train it is the rails that bear the thrust" (Maxwell, 1862, p. 712). In brief, Maxwell simply stressed that a transformation of energy should not be confused with the activation energy that triggered off that transformation.

In 1865 the French physician Claude Bernard published a book that was intended as an introduction to "experimental medicine". He stressed the peculiarity of biological processes, and at the same time the necessity of a scientific explanation: both determinism and guiding principles were at stake. The experimental method called into play determinism, because determinism was nothing else but the possibility of reproducing experiments. Bernard swung between two opposite poles: on the one hand, he put forward a strong process of reduction of life sciences to physics and chemistry, and on the other, he stressed the specific features and "the essence of life". The more demanding task was the clarification of that specific nature or essence: life required a sort of "guiding *idea*" or principle, or "creative idea", which "manifested itself in the organisation" of living beings (Bernard, 1865, pp. 6–8, 116–20, and 159–62).

In 1872, in the first part of a lecture he delivered to the German association of scientists and physicians, the German physiologist Emil Du Boi-Reymond took a different pathway. He claimed that scientific knowledge consisted in "reducing all transformations taking place in the material world to atomic motions". Since mechanical laws could be translated into the mathematical language, they could rely on "the same apodictic certainty of mathematics". The universe was ruled by "mechanical necessity": its present state could be "directly derived from its previous state", and could be looked upon as "the cause of its state in the subsequent infinitesimal time". He mentioned Laplace's Mind [ein Geist], and represented *It* as a powerful entity that would be able to "count the number of hair in our heads". Although "the human mind will always be remotely distant from this perfect scientific knowledge", what he labelled "Laplace's Mind" represented "the highest conceivable stage of our scientific knowledge" (Du Bois-Reymond, 1872, pp. 441–4 and 446).

The following year Maxwell wrote a brief essay that was not intended to be published: it was addressed to a club of scholars who had the habit of sharing their reflexions and cogitations. Once more he was interested in the relationship between mind and body, and instabilities and "singular points" were at stake. He found that "the soul of an animal" was not structurally different from "a steersman of a vessel" whose "function" was "to regulate and direct" the energy rather than "to produce" it. Instability was the key word and the key concept, and physics offered some instances of instability. Maxwell saw an intrinsic connection between instability and free will: when "we more or less frequently" found ourselves "on a physical or moral watershed", we also found the same features of the physical instability. In the moral state that corresponded to physical instability, "an imperceptible deviation" was "sufficient to determine into which of two valleys we shall descend" (Maxwell, 1873, pp. 817–21).

In the same year the Scottish physicist Balfour Stewart published an "elementary treatise on energy and its laws". The book had great success, and it was repeatedly reprinted in the following years. In the last chapter, which was devoted to "the position of life", he discussed physical and chemical instabilities, and some structural analogies with life. Both the natural world and scientific practice offered two kinds of "machines or structures": the former were characterised by their stability and "*calculability*", and the latter by their instability and "*incalculability*". Astronomical predictions represented the best instance of calculability whereas explosions, together with their "sudden and violent transmutation of energy", represented the best instance of incalculability. Living beings represented the third level of instability and incalculability after the mechanical and the chemical, and their complexity exceeded at length the complexity of first and second level machines. A different kind of action was involved indeed, because "the power of an animal, as far as energy is concerned", was not "creative, but only directive". It is worth remarking that he did not expect "to have discovered the true nature of life itself"; he had only confined himself to pointing out a very general operating principle, which offered a useful analogy (Stewart, 1873, pp. 155–9 and 161–3).

In 1844 Mayer had been puzzled by processes involving a sudden release of *force*, and in 1876 he devoted a short paper, "Ueber Auslösung", to the subject. From the outset, the two key words and concepts were "sudden release [Auslösung]" and "triggering action [Anstoß]" or impulse, and both concepts were involved in explosive processes: the latter could be looked upon as the first stage of the former. Triggering processes played an important role in life sciences, in particular "in physiology and psychology". Even in organic chemistry, and more specifically in the phenomena of fermentation, the *Auslösung* was at stake: human life depended on a network of processes of that kind (Mayer, 1876, pp. 104–6).

2. Mathematical and physical perspectives on differential equations

Instabilities and singularities were also at stake in the mathematical field. In the context of differential equations, the existence and uniqueness of solutions, and the role played by singular solutions were still under scrutiny around 1880: no systematic, conclusive, and universally accepted theory was on the stage. Only around the turn of the century a satisfactory systematisation was achieved.[2] With regard to singular solutions, some mathematicians had already come across them in the eighteenth century: among

[1] In the firs page of his paper he had claimed that "forces are causes" (Mayer, 1842, p. 1).

[2] Twenty years ago the historian of mathematics Christian Gilain stated that "the theory of ordinary differential equations still appears to be one of the most active branches of mathematics" (Gilain, 1994, p. 451).