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Models, theory structure and mechanisms in biochemistry: The case of allosterism☆

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ABSTRACT

From the perspective of the new mechanistic philosophy, it has been argued that explanatory causal mechanisms in some special sciences such as biochemistry and neurobiology cannot be captured by any useful notion of theory, or at least by any standard notion. The goal of this paper is to show that a model-theoretic notion of theory, and in particular the structuralist notion of a theory-net already applied to other unified explanatory theories, adequately suits the MWC allosteric mechanism explanatory set-up. We also argue, *contra* some mechanistic claims questioning the use of laws in biological explanations, that the theory reconstructed in this way essentially contains non-accidental regularities that qualify as laws, and that taking into account these lawful components, it is possible to explicate the unified character of the theory. Finally, we argue that, contrary to what some mechanists also claim, functional explanations that do not fully specify the mechanistic structure are not defective or incomplete in any relevant sense, and that functional components are perfectly explanatory. The conclusion is that, as some authors have emphasized in other fields (Walmsley 2008), particular elements of traditional approaches do not contradict but rather complement the new mechanist philosophy, and taken together they may offer a more complete understanding of special sciences and the variety of explanations they provide.

1. Introduction

Mechanicism is commonly regarded as a version of causalism that is particularly relevant in some special sciences, in particular in molecular biology, biochemistry and neuroscience, in which the notion of explanatory mechanism proves especially useful and is widely used. Although mechanicism is not a homogeneous program, and authors diverge in some relevant respects (cf. e.g., Machamer, Darden & Craver (henceforth, MDC) 2000; Bechtel & Abrahamsen, 2005; and Craver, 2007a for a survey), the main representatives of the new mechanistic philosophy share certain tenets with regard to theorization, explanation and lawfulness. In this paper, we focus on two families of questions. On the one hand, some mechanists claim that in these fields the talk of theories, and laws, is inappropriate, unnatural, or useless (cf. Craver & Darden, 2005; Machamer, Darden, & Craver, 2000), while others defend that one can legitimately talk of theories but that no standard notion of 'theory', either in the Received View or in semantic approaches, is of useful application (Craver, 2001). On the other hand, regarding functions, mechanisms and explanation, some relevant mechanists claim, mainly referring to biochemistry, that mechanistic explanations are fully causal, and that functional explanations that are not fully mechanistically specified are somehow "defective" (provisional, incomplete, elliptical) (Craver, 2006, 2007a,b, 2008; Piccinini & Craver, 2011).

We take as our main case study the Monod-Wyman-Changeux theory of allosterism (MWC), formulated in clearly mechanistic language by the authors themselves, who talk of the "allosteric mechanism" (Monod, Wyman, & Changeux, 1965, p. 103). Although we acknowledge that mechanist philosophers are right in emphasizing that in special sciences most scientists invoke mechanisms

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when they intend to explain a phenomenon (Machamer et al., 2000; Bechtel & Abrahamsen, 2005; Kaplan & Craver, 2011 [1]), we argue, *contra* some of their additional claims mentioned above, in favor of the following four claims. (a) The MWC explanatory set-up can properly be regarded and reconstructed as a theory in a strong sense; more specifically, as a unified net-like theory structurally similar to, yet simpler than, other highly unified explanatory theories such as Classical Mechanics (CM), Phenomenological Thermodynamics or Classical Genetics. (b) The notion of theory applicable here belongs to the semantic or model-theoretic family; more specifically, it is the one explicated by Sneedian structuralism. (c) MWC essentially contains modal, nomological components that can properly be considered law-like in a relevant, though minimal, sense of lawhood. (d) The non-fully mechanistic, functional components are perfectly explanatory, according to a plausible notion of explanation.

In section 2 we introduce the discussion on the use of the notion of theory in molecular biology and biochemistry, and what we take to be the main issues of the debate. In section 3 we introduce the relevant notion of theory at stake; namely, the structuralist notion of *theory-net*. In section 4 we offer a brief historical and conceptual presentation of MWC and informally reconstruct its models and its structure. In section 5, we discuss the relation between theories, laws, mechanisms and functional components in MWC explanations. We conclude by summarizing our main claims and their significance for the debate.

2. Theories and mechanisms

MDC have questioned whether the/any notion of theory is of useful application for many mechanistic explanatory practices, in particular in brain and molecular sciences:

> There are several virtues of the causal-mechanical approach to understanding scientific explanation in molecular biology. For one, it is truest to molecular biologists' own language when engaging in biological explanation. Molecular biologists rarely describe their practice and achievements as the development of new *theories*; rather, they describe their practice and achievements as the elucidation of molecular *mechanisms* (Darden & Tabery 2009, Section 3.2, referring to Machamer et al., 2000; Craver, 2001).

It must be stressed that Craver accepts that a certain broad notion of theory is applicable across all disciplines and that it is useful for understanding scientific practice. However, he doubts that the two dominant accounts of theories, the syntactic or axiomatic and the semantic or model-theoretic accounts, provide any useful notion of theory of general application—and much less so in mechanistic theories (Craver, 2001, p. 55). Here, when Craver refers to "the two dominant philosophical analyses of theories", he is thinking of what he calls the ORV (syntactic) and the MM (semantic) views, and it must be emphasized that, regarding the latter, he only takes into account Suppe's analysis. Craver does not deny that there is a general notion of theory that is applicable, but he confines it to what he calls the *formal aspects/patterns*. Although he does not specify what he understands by 'formal' here, the passage seems to imply that most of the important issues are neglected or excluded.

We think that Craver is right in saying that there are important aspects of theories that cannot be expressed by any (general) notion of theory on the market. For example, the mechanistic (or non-mechanistic) nature of a theory cannot be expressed by any (general) notion of theory; nor can whether a theory is, or is not, causal; or whether it is, or is not, materialist; and so forth. But the problem is not to do with formal *vs* non-formal aspects, but with generality. No *general* notion of theory, already current or forthcoming, can express these facts. If the notion is really general, it should apply to both mechanistic and (if there are any) non-mechanistic theories; to both causal and (if there are any) non-causal theories; to both materialist and (if there are any) non-materialist theories.

We acknowledge that these are very important aspects to be discovered about theories, and thereby agree that there are important features (besides their specific content) that deserve philosophical attention and that have not yet been explicated by a general notion of theory. Such aspects are the subject for other, more restricted notions that apply only to a specific family of theories. For instance, unless one could conceptually exclude the existence of non-mechanistic theories, no *completely general* concept of theory could express the mechanistic aspects. And we know that Craver, and mechanists in general, do not believe that non-mechanistic theories are conceptually impossible (unless we trivialize the notion of mechanism). Nonetheless, we believe that this fact does not imply that a general notion of theory is of little interest in molecular biology, biochemistry and neuroscience—the paradigmatically mechanistic scientific fields. Thus, although it is of great importance to emphasize the relevance of the study of mechanistic aspects in many fields (and mechanist philosophers deserve recognition in this regard), there may be other aspects, even in mechanistic theories, that are more general and of equal or complementary importance. We believe that these other aspects deserve to be analyzed by applying a broader concept of theory.

At this point, especially in these pluralistic times, a mechanist may disagree and claim that there is no general notion of theory that is *both* applicable *and* of interest regarding mechanistic theories. Of course this is true if our interest is confined to the mechanistic aspects of mechanistic theories. But we believe that mechanistic theories involve other non-mechanistic aspects, which are of philosophical interest as well; and that the general Sneedian structuralist concept of *theory-net*, is useful for the analysis of such aspects, or at least of some of them. The following are just three examples of relevant issues concerning which, such a concept has proven fruitful.

- The net-like structure of a theory-net, with its top, essential components and bottom, modifiable ones, is crucial for the understanding of important features related to theory-testing and theory-change emphasized by philosophers and historians of science such as Kuhn and Lakatos, and thus for clarifying whether, or in what sense, theory-nets are falsifiable (Díez, 2007; Kuhn, 1976).
- The distinction between T-theoretical and T-non-theoretical concepts for theory T is essential for responding to some unacceptable versions of theory-ladenness: T-data are T-non-theoretically identified, so they may be theory loaded by another theory, T^*, but never by the same theory, T, in which they behave as the basis for testing (Balzer, Moulines, & Sneed, 1987).
- The hierarchized structure of nomological constraints, introduced in the notion of theory-net, is also useful for clarifying the unified nature of some theories and the related part of the

[1] For example, here the authors claim that Hodgkin and Huxley's (1952) equations do not explain how voltage changes the membrane conductance since the mechanism is not fully specified: "The explanation required the idea of a voltage-sensitive, membrane-spanning channel, which only came dimly into view in the 1970s and 1980s." (Kaplan & Craver, 2011).