Studies in History and Philosophy of Biological and Biomedical Sciences 53 (2015) 84–93

Contents lists available at ScienceDirect

Studies in History and Philosophy of Biological and Biomedical Sciences

journal homepage: www.elsevier.com/locate/shpsc

Can mechanistic explanation be reconciled with scale-free constitution and dynamics?

William Bechtel

Department of Philosophy, Center for Circadian Biology, and Interdisciplinary Program in Cognitive Science, University of California, San Diego, United States

ARTICLE INFO

Article history:
Available online 11 May 2015

Keywords:
Mechanistic explanation
Idealization and abstraction
Scale-free dynamics
Scale-free small world networks

ABSTRACT

This paper considers two objections to explanations that appeal to mechanisms to explain biological phenomena. Marom argues that the time-scale on which many phenomena occur is scale-free. There is also reason to suspect that the network of interacting entities is scale-free. The result is that mechanisms do not have well-delineated boundaries in nature. I argue that bounded mechanisms should be viewed as entities scientists posit in advancing scientific hypotheses. In positing such entities, scientists idealize. Such idealizations can be highly productive in developing and improving scientific explanations even if the hypothesized mechanisms never precisely correspond to bounded entities in nature. Mechanistic explanations can be reconciled with scale-free constitution and dynamics even if mechanisms as bounded entities don't exist.

When citing this paper, please use the full journal title *Studies in History and Philosophy of Biological and Biomedical Sciences*

1. Introduction

Fundamental to the project of mechanistic explanation, both as pursued in biology over the past two centuries and as characterized by the proponents of the *new mechanistic philosophy of science*, is the identification of mechanisms responsible for phenomena for which explanation is sought. Mechanistic explanations then attempt to decompose these mechanisms into their parts and operations and show that when appropriately organized these components can generate the various phenomena. A natural interpretation of this approach to explanation is that mechanisms and their components exist as well-delineated entities in nature and operate on characteristic timescales. A good mechanistic explanation describes the responsible mechanism (Craver, 2007). Marom (2010) raises a serious and important objection to this account of mechanisms by showing that many biological (including psychological) phenomena do not exhibit a characteristic time-scale. The time-course of the phenomenon is scale-free so that there is no well-delineated temporal window in which a hypothesized mechanism could generate this phenomenon. Operations in the distant past of the mechanism itself affect how it operates in the present.[1]

While Marom's objections focus on the temporal dimension, similar concerns can be raised about the constitution of a mechanism at a given time. While mechanisms are assumed to receive inputs from outside and send outputs to other entities, they are generally taken to be bounded entities that are responsible for a phenomenon. This is manifest in the style of diagram Craver (2007) uses to represent a canonical mechanism (Fig. 1). The mechanism (bottom) responsible for a phenomenon (top) is represented as an oval with a sharp boundary surrounding its components and separating them from what then counts as the external environment.[2]

[1] In Braun and Marom (in this issue) this is raised primarily as a problem in relating processes at different levels of organization. This is directly relevant to mechanistic explanations, since they involve appealing to operations that are at a lower level to explain phenomena that are at the level of the whole mechanism.

[2] The parts of a mechanism need not be spatially segregated. Entities that are not regarded part of a mechanism can be interspersed with those that are construed as part of a mechanism. What matters in delineating the mechanism is that the entities are viewed as causally interacting in the production of the phenomenon in question.

E-mail address: Bechtel@ucsd.edu.

http://dx.doi.org/10.1016/j.shpsc.2015.03.006
1369-8486/

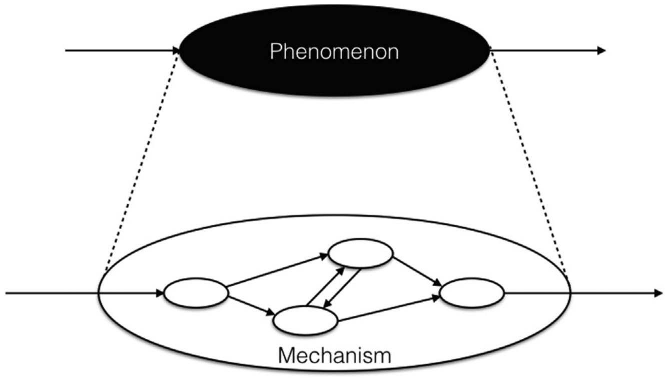

Fig. 1. Craver (2007) style representation of a mechanism responsible for a phenomenon (top) as a dark oval enclosing component mechanisms (bottom).

The mechanism is distinct but not isolated: one arrow penetrates the boundary to affect one component, and another arrow extends outwards from a different component. These arrows represent the fact that other entities in the environment (not explicitly shown) connect causally with certain parts of the mechanism of interest.[3] These external entities may be ions at some concentration in a fluid, or may themselves be mechanisms, or whatever else may be causally salient. Inside the boundary, each part (represented by a smaller oval) performs one operation—Craver's way of conveying that each of these constituent ovals can itself be regarded as a mechanism that could be unpacked into its own parts and operations. Each oval (the large one and the several small ones) delineates a mechanism distinct from others. Successful mechanistic explanations at each level, on this view, explain the behavior of mechanisms in terms of their constituents.

This picture, however, is highly misleading, as I will argue in Section 3. The parts and operations taken to constitute a mechanism responsible for a given biological phenomenon are often found to have a multitude of causal interactions with entities and activities initially taken to be outside the mechanism. Whereas Fig. 1 suggests very sparse causal relations crossing the boundary—involving what are often regarded merely as inputs and outputs—there are frequently so many interactions that the practice of designating discrete mechanisms is called into question. When represented in a graph theoretical manner, the parts and operations can be seen as entities within large networks that are also scale-free in the sense that there is not a well-defined scale on which to characterize the boundaries of the mechanism within the network.

Marom's appeal to scale-free time-scales and the recognition that the parts of mechanisms are enmeshed in scale-free networks both reveal that mechanisms are not sharply delineated in nature. Explanations do not simply characterize mechanisms differentiated by well-defined boundaries. Rather, scientists propose mechanisms as they develop mechanistic explanations. That is, they hypothesize that entities are organized together as parts of a mechanism and through their coordinated operations produce the phenomenon. It is the scientists who impose boundaries around entities and activities in nature and impose a time scale on which their functioning is characterized. For different explanatory purposes researchers may draw these boundaries in different locations or at different time points. These choices, though, while not simply responsive to pre-existing boundaries, are not entirely arbitrary. As I discuss in Section 4, the networks of entities found in nature commonly exhibit small-world organization as well as being scale-free. This entails that while real-world networks are highly interconnected, there are clusters within them that are semi-independent of the rest and productively posited to be the mechanisms responsible for specific phenomena.

While not arbitrary, mechanism posits are nonetheless idealizations in that they misrepresent the behavior of the mechanism as due solely to its components and their organization; they neglect the roles interactions with other entities play in determining the mechanism's behavior. Godfrey-Smith (2009), among others, distinguishes idealization from abstraction: whereas abstraction involves merely leaving out information, idealization involves the introduction of simplifying falsehoods in a model. Assuming that activities in a mechanism are not affected by entities outside its boundaries (except for those distinguished as providing inputs) or activities outside its time-window involves abstraction, but these assumptions are false and simplifying. Hence, these assumptions are also idealizations (although typically not adopted with the awareness that they are false).

In arguing that the idealized accounts of mechanisms are nonetheless valuable as mechanistic explanations, I invoke the perspective Richardson and I (Bechtel & Richardson, 1993/2010) introduced: explanations that localize phenomena in parts of a system, when successful, are only accurate to *a first approximation*. Starting from such a localized explanation, further research often unveils the interconnections of those components with others. Researchers who seek to pursue these effects then expand the boundaries of the mechanism. The expanded account, however, is still not a complete account and it would be both unrealistic and unproductive to try to incorporate all relevant factors in an explanation.[4] The mechanism hypothesized in a mechanistic explanation remains an idealization in that it fails to give a fully correct account of the phenomenon occurring in nature.

In Section 5 I turn specifically to Marom's argument that the time-scale on which biological phenomena are produced is scale-free. I construe this as providing further evidence that the mechanisms hypothesized in mechanistic explanations are idealizations. But there is an alternative perspective: such results can be viewed as pointing to the need to supplant mechanistic explanation with an alternative type of explanation that employs an appropriate mathematical framework to accommodate activity on scale-free time-scales. This seems to be the perspective favored by Braun and Marom (in this issue). While granting the value of appropriate mathematical representations, I argue for the continued pursuit of mechanistic explanations that impose time-windows in which the activity of a mechanism is hypothesized to operate. Such research is extremely valuable in revealing components that account for the phenomenon of interest to a first approximation. Once an account that sufficiently approximates the phenomenon is developed, then expanding the time-window can allow for incorporation of more effects, leading to improved approximations when desired.[5]

[3] In characterizing the components of a mechanism, Bechtel and Abrahamsen (2005) refer to parts and operations while Machamer et al. (2000) speak of entities and activities. I will use *parts* and *operations* for the components of a mechanism and *entities* and *activities* for mechanisms themselves, including those with which the mechanism posited in a give inquiry is taken to interact.

[4] Typically, as researchers expand the boundaries of what they take to be the mechanism responsible for a given phenomenon, they simplify their characterization of the components initially identified. This again entails that the mechanisms posited are idealizations.

[5] In the conclusion of their paper, Braun and Marom (in this issue) characterize this stance as "conservative reductionism." I accept that the strategy of mechanistic explanation is reductionistic, but view the pursuit of mechanistic explanations as a heuristic strategy that idealizes and requires continual revision as it inevitably falls short of fully accounting for target phenomena. As such, it deviates from truly conservative accounts such as Craver's that embrace mechanistic explanations as striving to correctly describe the world.