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# Carl F. Craver and Lindley Darden: *In Search of Mechanisms: Discoveries Across the Life Sciences*

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Carl Craver and Lindley Darden are two of the foremost proponents of a recent approach to the philosophy of biology that is often called the New Mechanism. In this book they seek to make available to a broader readership insights gained from more than two decades of work on the nature of mechanisms and how they are described and discovered. The book is not primarily aimed at specialists working on the New Mechanism, but rather targets scientists, students and teachers who are looking for a broad, philosophically and historically informed image of discovery in the life sciences.

The best feature of this book is its thoughtful use of examples to illustrate what mechanisms are and how scientists search for them. Craver and Darden draw examples from across biology and the life sciences and from the birth of mechanistic approaches in the seventeenth century to the present day. Many of these examples will be familiar to readers of Craver and Darden's other works—synaptic transmission, the action potential, protein synthesis and spatial memory—but there are others which are new to this book. There is for instance a careful description of William Harvey's investigation of the mechanisms responsible for circulation of the blood as well as a discussion of contemporary research on the mechanisms responsible for cystic fibrosis. Craver and Darden have taken care to describe their examples thoroughly, while at the same time offering enough background to allow readers unfamiliar with the relevant biology to understand their points. Collectively these examples provide an inductive basis for the claim that much of the scientific activity across the life sciences can be understood as a search for mechanisms.

In their attempt to make this book accessible to this audience, Craver and Darden have written the book in a style that eschews many philosophical conventions. Their first rule, as they put it, is that they will ''stay positive'' (p. xviii), which is to say that they do not frame their mechanistic approach in opposition to other models of science and scientific discovery, nor do they discuss or

respond to the many commentaries upon and criticisms of their work or of the work of the New Mechanists more generally. Except for brief bibliographic essays at the end of each chapter, the book is very light on references and without footnotes.

Another of Craver and Darden's principles is to ''avoid when possible the proprietary jargon of philosophy and favor plain descriptive terms.'' Here they are only partially successful. While the book does indeed avoid many specialized philosophical discussions, the book is largely organized around the elaboration of terms of art within the New Mechanism, especially the terminology originally introduced in ''Thinking about Mechanisms''(2000), the seminal paper Craver and Darden co-authored with Peter Machamer, which remains the most widely cited paper in the literature of the New Mechanism. Their account of what a mechanism is begins with the well-known characterization from that original paper: ''Mechanisms are entities and activities organized such that they are productive of regular changes from start or set- up to finish or termination conditions'' (p. 15). Similarly, their account of scientific representation is formulated within their proprietary terminology of mechanism schemas and sketches, and their account of strategies for mechanism discovery is organized around concepts Darden and Craver have developed over the years (e.g., Craver and Darden 2001; Darden and Craver 2002; Darden 2002).

While use of this terminology is neither unexpected nor inappropriate, I wish that Craver and Darden had used this opportunity to revise some of their original language in light of what has been learned in the last decade of discussion. For instance, the original (Machamer et al. 2000) formulation required that mechanisms operate from ''start-up to termination conditions'', but this requirement has been widely criticized as being too restrictive, and in the text Craver and Darden readily point out that ''not all mechanisms work like that'' (p. 18). Similarly, Craver and Darden would have been better off to build into their basic characterization of a mechanism the idea that a mechanism is always for some phenomenon. This idea is widely established in the literature (e.g., Craver 2007; Glennan 1996; Illari and Williamson 2012) and accepted by the authors

themselves, and it would be helpful if their account of what a mechanism started with this key feature.

In fact, one of the most illuminating themes of Craver and Darden's book is their exploration of the interplay between phenomena and the mechanisms responsible for them—or better, between our representations of the phenomena and our representations of those mechanisms. As Craver and Darden show, the proper characterization of the phenomenon is a non-trivial achievement that is a central preliminary to searching for a mechanism; also they show how phenomena are often mischaracterized and how in the process of mechanism discovery, they often need to be recharacterized.

One new and helpful aspect of their discussion of phenomena is their identification of three different kinds of relationships between mechanisms and their phenomena: Some mechanisms *produce* their phenomena, while others *underlie* their phenomena and others *maintain* their phenomena. The production relation is the one most closely connected to Machamer et al's original formulation of production from start-up to termination conditions; the underlying relation characterizes the sort of inter-level relation between mechanisms and phenomena explored at length in Craver (2007), while the maintaining relation is one that has not been as prominent in earlier work. In a maintaining mechanism, a system is, with respect to some properties or aspects of its functioning, in a steady state— for instance, a steady body temperature or metabolic rate within an organism–and the maintaining mechanism is responsible for keeping the system in this state in the face of environmental or other perturbations. Such mechanisms, while they do require activities, dampen or prevent change rather than produce it. Given that mechanisms of this kind are ubiquitous within living systems, Craver and Darden are wise to explicitly show how this kind of mechanism—phenomenon relation fits within their account.

Craver and Darden's account of mechanism schemas (what are more commonly called models) starts with the claim that schemas vary on four dimensions—completeness (from sketch to

schema), detail (from abstract to specific), support (from how-possibly to how-actually) and scope (from narrow to wide) (p. 30). These ideas are central to their account of discovery, as their story about mechanism discovery is a story about how various kinds of observations and experiments, as well as other considerations such as inter-field integration, lead one from sketches to schemas and from accounts of how-possibly to how- actually. While they assert at one point in the book that these dimensions are independent, much of the value of their account lies in showing the ways in which these dimensions are not independent. For instance, evidential support grows as we fill in the black boxes to make them more transparent—which is a matter of completing the sketch and adding details. Similarly, detail is often bought at the expense of scope.

One of the most interesting questions raised by Craver and Darden's book concerns the scope of the New Mechanism. The authors are careful not to claim too much. Science, they say, ''is not defined as the search for mechanisms'' (p. 7) because there are many worthy scientific pursuits that are not obviously mechanistic. It is possible to describe and predict patterns in phenomena without knowing the mechanisms that are responsible for those patterns. But at the same time, the account they have given is one that naturally leads to a view that suggests that the search for mechanism is and should be the central activity of modern science. As they put it:

> The fact that biology has become a search for mechanisms is not merely a matter of fashion. Biologists look for mechanisms because they serve the three central aims of science: prediction, explanation and control (p. 6).

Here they echo the words of the ecologist Simon Levin who says of biology, and of science generally, that ''the key to prediction and understanding lies in the elucidation of mechanisms underlying observed patterns'' (Levin 1992, p. 1943). You can find patterns without mechanisms, but unless you have mechanisms, you don't understand why the patterns are there, whether they will continue to hold, and how, if you wish, you might change them.

Craver and Darden's brief is to argue for the centrality of mechanisms in biology, not across the wider expanse of science. But while there evidence is drawn from biological examples, there is little in their characterization of mechanisms and how we look for them that is specifically biological. The entities and activities may be different, but that is not essential—indeed the diversity of entities and activities is a central and attractive part of their story. The strategies they discuss—from experimental design to anomaly resolution—are relevant across a range of sciences. For this reason, this book will be of interest not just to those interested in biology and the life sciences, but to anyone interested in the process of scientific discovery generally.

Craver and Darden cannot resist the self-referential application of their account of discovery to their own project. The first sentence in their preface (echoed in the last paragraph of the book) asserts that ''science is an engine of discovery.'' This means, of course, that science is a mechanism that produces discoveries. If they have rightly characterized the phenomena—as I think they have—*In Search of Mechanisms* offers us a model (or, as they might say, say a partially filled in schema) of how this mechanism works. That model is not, as they would be the first to agree, a wholly new invention. It involves refinements and revisions of earlier models, including those of philosophical luminaries like Popper, Hempel, Hanson and Kuhn. That is how the engine of the history and philosophy of science works.

It is one of the truisms in the philosophical literature that all models involve trade-offs. The point is emphasized in Craver and Darden's own discussion of mechanism schemas, and we can apply it to the model of mechanism discovery they give us in their book. Theirs is a model of wide scope; it sometimes trades philosophical precision for cross-disciplinary accessibility; it contains idealizations and approximations that do not apply everywhere. Still, in my view, they succeed admirably in their main explanatory purpose—to illuminate for a larger public, the workings of the engine of scientific discovery.

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