force of gravity acting at a distance, which allows him to illustrate the instrumentalism/realism issue. As a culmination of the development of the Newtonian worldview right before its collapse, the author mentions the physics of electromagnetic fields developed by Faraday and Maxwell. But this is a sort of physics that these scientists explicitly opposed to the Newtonian models based on action at a distance between particles.

JORDI CAT
Department of History and Philosophy of Science
Indiana University

Representing Electrons: A Biographical Approach to Theoretical Entities
THEODORE ARABATZIS
Chicago, University of Chicago Press, 2006
xiv + 295 pp., ISBN 0226024202, US$70.00 (hardback); ISBN 0226024210, US$28.00 (paperback)

Theodore Arabatzis's book, *Representing Electrons*, is a fine piece of work in the history and philosophy of science. The bulk of the book is a history of representations of the electron, from 1891, when the term was introduced, to 1925, when Goudschmit and Ulenbeck suggested the notion of intrinsic spin. This history takes the form of a biography and is based on a distinction between the representations of the electron that figure in theories, and the electron itself as the purportedly real unobservable entity to which such representations refer. Arabatzis refers to the representations as 'theoretical entities'. As representations, they are constructed by scientists and embedded in various theoretical contexts. According to Arabatzis, the goal of a biography of a theoretical entity is to understand how it functions in scientific practice, and this requires first identifying it, and then tracking its development over time, much as one would do in writing a literary biography. Just as with literary biographies, biographies of theoretical entities may be fictional or non-fictional. Arabatzis sees this as an advantage for the historian, allowing him or her to remain neutral in debates over scientific realism, and this is particularly relevant in dealing with episodes of discovery in the history of science. Arabatzis, however, is not averse to addressing such philosophical concerns. The last chapter of the book suggests what philosophy of science can learn from a biography of representations of the electron, indicating in particular what a scientific realist would have to do to convert such a biography into a work of non-fiction.

The first two chapters of the book provide a preliminary discussion of the methodology underlying Arabatzis's biographical approach. The general idea is to emphasize theoretical entities, as opposed to the theories in which they are embedded, as the subject of historical analysis. Moreover, the biographical approach stresses the active participation of theoretical entities in historical episodes, as well as their stability (as biographical subjects) over time. These features are supposed to distinguish the biographical approach from other concept-oriented (viz., thematic) approaches to history of science. In slightly more detail, according to Arabatzis, theoretical entities

have two essential features that make them advantageous to the historian. First, they have an experimentally determined component that is relatively stable. Thus, they are 'independent to some extent' of theories, or, as Arabatzis would have it, they have a 'life of their own' (41). Second, Arabatzis maintains that theoretical entities are 'active participants' in the development of science in two senses: (1) they 'resist' change in so far as they come fully clothed in laws and properties (i.e. those features that allow them to be embedded in a given theoretical context); and (2) they embody heuristic resources, in so far as they may suggest new questions and problem situations. From a historiographical point of view, as active participants, theoretical entities provide explanatory resources for historians. Furthermore, the alleged stability of theoretical entities over time avoids problems with concept and meaning variance over theory change, and also allows theoretical entities to cut across disciplinary boundaries.

At this early stage, Arabatzis is keen to make clear a number of caveats associated with the biographical approach. First, he maintains that the term 'biography' is used metaphorically. In particular, he insists that the active agency he imparts to theoretical entities should not be taken as attributing intentionality to them (46). Second, he stresses that realism is not a presupposition of the biographical approach, making an analogy with literary biographies of fictitious personalities: Hamlet, for example (49). Two quick concerns may be voiced at this point. First, if the active agency of theoretical entities is purely metaphorical, it is not clear what work it does in distinguishing the biographical approach from other concept-oriented approaches to history of science. Second, one might argue that the biographical approach is not completely neutral with respect to realism. In so far as theoretical entities obtain their 'agency' and stability from being constructions based on observational data, the biographical approach assumes a realist stance with respect to such data. Such data are what Arabatzis refers to frequently as the electron's 'writings', and while he takes a neutral stand with respect to the ontological status of the electron qua unobservable entity, he is a realist with respect to its writings and, moreover, explicitly attributes them to the electron qua unobservable entity. (It is here that the analogy with fictitious literary biographies might be seen as breaking down.) Indeed, the biographical approach in general seems heavily influenced by constructive empiricism in its distinction between unobservable entities, of whose existence we should remain agnostic, and observable data, to which we have unproblematic epistemic access.

In Chapter 3, Arabatzis provides a critique of the received view of the discovery of the electron, which attributes it to Thomson when in 1897 he measured the charge-to-mass ratio e/m (subsequently measuring the charge e in 1899). Arabatzis argues against a number of proponents of the received view, claiming that all implicitly or explicitly adopt questionable realist presuppositions. In keeping with the professed neutrality of the biographical approach, Arabatzis adopts a pragmatic criterion of discovery under which discovery amounts to the formation of a consensus with respect to the existence of the alleged entity. He then demonstrates that such a consensus did not form until well after 1897. The remainder of the book, with the important exception of the last chapter, consists of a historically detailed and informative biographical

narrative tracking the development of representations of the electron from their 'birth and infancy', through quantum and relativistic representations, and culminating in representations characterized by intrinsic spin. Arabatzis concedes that it is a selective history, the primary purpose of which is to provide examples of the agency of representations of the electron, and their stability both diachronically across theory change and synchronically across disciplines (the primary example of the latter is a discussion in Chapter 7 of the contrasting representations of electrons in physics and chemistry during the 1900s to 1920s).

The concern of the last chapter is ultimately how a biography of theoretical entities, purportedly neutral with respect to scientific realism, could be turned into a work of non-fiction. The chapter opens with a discussion of the debate over meaning variance across theory change. If the meaning of theoretical terms changes when theories change, and if Arabatzis's theoretical entities are identified with theoretical terms, this bodes ill for the biographical approach. If theoretical entities do not have a stable identity over time, biographies of them will be very short: 'Hamlet Appears in Scene One In Which His Charge-to-Mass Ratio is Measured. End of Story'. To address this concern, Arabatzis adopts a definition of the meaning of a theoretical term, slightly modified from one proposed by Feyerabend; namely, the meaning (or concept) associated with a theoretical term amounts to the set of features that are ascribed, by the theory in which the term is embedded, to the corresponding entity (242). In keeping with the neutrality of the biographical approach, this definition involves minimal philosophical baggage. Arabatzis now observes that realism is compatible with meaning change, so construed, given that a core set of properties survives theory change. Such a realism would claim that stability over theory change is a necessary condition for a set of properties to be awarded ontological status. Now, this might address a semantic realist's desire to identify which parts of a theory to read literally (i.e. which theoretical entities to take seriously), but it offers little for an epistemic realist who desires good reasons to believe that such parts really represent real things. Arabatzis acknowledges this, framing it as a challenge to the claim that a stable core of properties enables realism. This challenge is the task of identifying the criteria that privilege belief in the core over unstable beliefs. Ultimately, Arabatzis is satisfied to point out that this epistemic task is not faced by the biographer of theoretical entities, whose primary concern is with the identification of stable properties.

Thus, the challenge of turning biographies of theoretical entities into works of non-fiction remains open. In detailing this challenge, and in indicating other ways in which philosophy of science impinges on and informs history of science, Arabatzis's book is effective and informative. It is an excellent example of the reciprocally enhancing roles that history of science and philosophy of science can play with respect to each other.

JONATHAN BAIN
Humanities & Social Sciences
Polytechnic University
Brooklyn, NY