

opportunities for some of the companies to grow with the demand for specific electronic components in avionics and other applications. The demanding specifications for high reliability and challenging new applications spurred innovation in a community that relished a technological challenge. The solution to key process difficulties could signify the difference between rapid growth and success or going out of business.

However, the requirement for electronic devices by the military suffered very severe fluctuations to which not all companies were able to adjust. Thus companies were equally as motivated to innovate for the military as to become independent of such contracts. Identifying new applications and forms of industrial cooperation were conceived as a means to address these market conditions.

Finally, the story of Silicon Valley is a compelling story of human personalities, some of whom are

already American cultural icons. Others are not so well known by non-specialists but certainly have stories, captivating beyond the recognition of the importance of their role in the evolution of technology and its economic impact. In this, the author has made good choices, portraying these individuals in their context and supplying enough attention to their personal and professional dreams and disappointments to make it an attractive narrative.

The final sentence of the book captures the overall argument in a nutshell: "Manufacturing districts grow and thrive only so long as they remain communities of learning, practice and collaboration". This is a tad romantic if we remind ourselves of some of the episodes of ruthless competition, labor conflict, bureaucratic imposition, borderline intellectual property practices and so forth. However, it succeeds in showing the significance of knowledge flows even when they can be turbulent.

Biography of the electron

Grant Otsuki

***Representing Electrons: a Biographical Approach to Theoretical Entities* by Theodore Arabatzis**

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Representing Electrons introduces episodes from the life of the sub-atomic particle to achieve three goals: demonstrate the utility of a biographical approach to the study of the history of science; argue for the centrality of historiography to the philosophy of science; and provide the rough beginnings for a realist approach to unobservable entities. It is a strong attempt to put the philosophy of science into productive conversation with the history of science. Through the biographical method, Arabatzis attends to both the continuity and change of the electron as a "theoretical entity" — a term Arabatzis uses as shorthand for 'the representation of an unobservable entity' — over time and across disciplines.

He follows the electron as an active agent, which both shapes, and is shaped by, the situations it finds itself in. In other words, this book is in part an

investigation of the manifold ways in which the development of the representation of the electron has been altered by theoretical structures, experimentation, and the agency of the electron itself as a theoretical entity. The insightful empirical chapters lead to a philosophical discussion, where Arabatzis ties together the threads he traces in the earlier sections in interesting, though preliminary, speculations regarding the future development of a scientific realism based on historiography.

The first three chapters introduce the methodological, philosophical, and historical bases of the book. In chapter 1, Arabatzis develops Popper's notion of the "problem situation", which provides the basic framework for the rest of the book. Echoing Popper, Arabatzis argues that the history of the electron must be understood as a history of problem situations: a succession of attempts to rectify issues raised by new experimental evidence or by the implications of a particular representation of a theoretical entity. Arabatzis positions this view against that of Kuhn, who saw different eras of science bracketed by discontinuous breaks in the broad conceptual structure.

The chapter continues by discussing the interconnectedness of the notion of scientific discovery with realism versus anti-realism debates. Arabatzis argues for his biographical approach in the second chapter. He clarifies his notion of "theoretical entity" as a representation of an unobservable entity constructed from experimental data. Here, 'construction' is used

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to emphasize the gradual and piecemeal process that produces these representations.

Furthermore, these representations are active agents in their own development. That is, it is not only empirical data that determines how the story unfolds; the electron itself sometimes leads and at other times resists moves made by scientists to develop accurate theories. This is similar to actor-network theory in its ascription of agency to non-human entities. In this book, the electron is a historical actor, almost like any of the people that appear in each episode; it is a product of its time but also grows out of the situations it finds itself in. Experimental data are like the writings left by a historical figure.

Arabatzis traces this actor's background, its acts and exploits, and interprets its 'writings'. In chapter 3, he argues against the "received view" of the discovery of the electron, which places J J Thomson as a central figure. Building on his discussion in the first two chapters, Arabatzis problematizes the accepted version by illustrating how the discovery of the electron must be understood as a long process of construction that cannot be reduced to a single or a few events.

He is also critical of the realist presuppositions that pervade such a view, dismissing them as philosophically and historically unfounded. Arabatzis considers other realist definitions of 'discovery', most notably Ian Hacking's use of the manipulability of entities as a basis for belief in their existence, but finds them insufficient. As Arabatzis points out, one might believe oneself to be manipulating that historical invisible entity phlogiston, but this does not mean that phlogiston exists.

Chapter 4 begins the biography with an account of the "birth and infancy" of the electron. Arabatzis traces the emergence and evolution of the word electron from its first use by George Johnstone Stoney in 1891. This chapter is fascinating for its re-interpretation of the early days of the electron, and for how it draws together multiple threads, such as language, experimentation, and theory, to show how the electron arose out of existing science.

Chapter 5 covers the pre-quantum adolescence of the electron, and argues that attempts to understand the quantum nature of the atom are closely tied to ideas of the nature of the electron. This chapter is a rich illustration of the ways that the representation of the electron pushed back against some attempts by scientists to work through problem situations and other times indicated a new direction to investigate.

The sixth chapter follows the maturation of the electron into a quantum entity by following the play between increasingly accurate measurements of several electronic phenomena and the transformation and enrichment of the representation of the electron. The seventh chapter turns our attention to the chemists of the time and their view of the electron as a static particle within the atom. This chapter illustrates the increasing independence of the electron as it crosses disciplinary boundaries. Chapter 8 traces the integration of spin to the representation of the electron in the final phase of its 'growth' into a quantum citizen.

The philosophical implications of the biography of the electron are covered in the final chapter. The primary lesson of the empirical section is that the electron is still 'growing'; its biography can never be finished. There is always something about the electron that slips through the structures we possess to understand it. Arabatzis's main goal could be said to be to find a way to investigate and speak about this slippage in a way that might eventually undergird a robust scientific realism.

He considers several questions. What do we mean when we use the term 'electron'? How are we justified in saying that the electron of the past is the same entity as the electron of a later time? What would we need to be able to claim that the electron exists? Although Arabatzis shies away from making strong philosophical claims, he shows how the notion of problem situations and his biographical approach could be used in an effort to answer such questions. Ultimately, these questions are for the historian as much as they are for the philosopher.