BOOK REVIEW

Mathias Grote. *Membranes to Molecular Machines: Active Matter and the Remaking of Life*. Chicago: University of Chicago Press, 2019. Cloth ISBN 9780226625157, $48.00. PDF ISBN 9780226625249, $47.99. EPB ISBN 9780226625294, $47.99.

> Research on simple model proteins…has helped to transform the concept of proteins at the molecular level, thereby changing what 'biological' or 'lifelike' referred to…. Life has been made mechanical at the molecular level by zooming in on objects that may have actually been as much chemical as biological…. Life isn't what it used to be because of research on objects such as this (180).

Mathias Grote's dense but fascinating four-chapter book (complete with a helpful technical glossary and extensive notes) is an effort to do what its author describes as "grab the plethora of fascinating histories beyond the gene" (xii). Grote (who from 2004–2008 earned a PhD working in a German molecular biological laboratory) moves beyond mid-century molecular genetics to provide a history-of-science account of subsequent developments in membrane and protein biology—developments that "look at protein molecular machinery as an instance of active matter" (xiii). This mechanical molecular narrative evolves in stages and underpins the enormously effective membrane research that has had a large impact on contemporary molecular and biochemical science, biotechnologies, and medicine. Grote shows how membrane research has come to be "based on different conceptual and technological premises" and thus has "engendered a different picture of bodies, cells, and life…" (xii). In great detail, Grote's chapters "describe the work of a generation of influential protagonists from the 1970s to 1990s, who had been shaping a novel molecular biology in these years" (xii). Further, he suggests, "since the 1990s, many more proteins, from those of our bodies to those of plants, animals, and microbes have become amenable to technologies pioneered with…model proteins, and a related mechanical understanding of their functioning has become predominant" (180).

Grote meticulously unfolds, in successive chapters, the emergence of the "molecular-mechanical vision" in terms of (1) research on membranes prior to 1970, (2) the subsequent relation of materials in test tubes to molecular structure and biological function, (3) the ramification of this new vision in synthetic biology, and, finally, (4) biotechnological and nanotechnological projects after 1980. He makes a case that developing notions of "active matter" (10) have countered an earlier stereotype of matter as inert and homogeneous.

Grote recognizes that the "molecular-mechanical vision" is a materialistic perspective pitched at a certain level and that another different vision pitched at another level (e.g., that of the whole organism) might have materialized. He does not explore, like Polanyi, intricate philosophical questions about the interrelation of levels of control in machines or in living entities, and this Polanyi wrinkle might interest him. Grote thus restricts his account to "how this novel molecular biopolitics has been put into place, or 'realized' in a material sense, by transforming the materiality of life in the hands and minds of scientists in the laboratory" (7). Or, as he later puts matters, "This book has been largely a history

of materiality as well as of approaches, instruments and methods" (201).

Although, taken as a whole, this book is a history-of-science account, it reminded this reader of Kuhn's famous history-of-science book, *The Structure of Scientific Revolutions*: the historical discussion hovers around larger and more perplexing metaphysical questions central to philosophy of science, and Grote recognizes this. In fact, he invokes an Ian Hacking comment on "entity realism," suggesting that entities that science can know are in fact "real" (14). Nevertheless, the author seems to back away from broader ontological implications of this view: he suggests only that his book shows clearly how and why scientists have come to regard "molecular machines" as real. He affirms that certainly there is an "epistemic dividend" (139) in the "molecular machine" account since it allows understanding. But alas, Grote seems not to know anything about Polanyi's earlier mid-twentieth century, discovery-centered account of science with its rich anti-Cartesian participant realism that focuses on the indeterminate future manifestations of real entities.

A mundane example in Grote's discussion makes pellucid what he calls the contemporary "powerful, materialistic vision of life" (1) that arose and has become pervasive in the last fifty years: The "proton pump inhibitor" (1) is a pill, easily available today for heartburn. After taking the pill, "gastric mucosa cells excrete fewer protons into the stomach, leading to less acid production" (2). The pill thus "alters the mode of operation of our body's 'molecular machinery,' thus modifying cellular physiology" (2). Grote chronicles how molecules for researchers became a "pump since there are mobile elements in its organization that push something over a distance in this case moved by the energy of light" (8). This mechanical image arose in opposition to "mathematical expressions of physics or theoretical biology, or to chemical formula in the reaction equation," and thus eventually the "explanation given here takes the form of a highly complex narration" (10). But the bottom line is rather mundane:

> If you can block the proton pumps in your gastric mucosa and record the effect both on the level of the protein (decreased function) as much as on that of the organism (decrease of acidity in the stomach, relief of pain), these pumps must have become real in some way to the scientific community, and to those endorsing its knowledge production. (14)

As Grote's detailed and nuanced discussion shows, it is not simply "pumps" but all kinds of mechanical (and later electrical) elements and processes that have slowly come to constitute the framework for understanding and manipulating membranes. This move has newly opened up questions about what life is:

> It is the material modeling of membranous objects and their dynamics—from mixing lipids and water for spontaneous membrane formation, to extractions, centrifugations, syntheses of "protocells" to the study of communication between cells and interactions with their environment—that has allowed membrane research to re-formulate and re-cast many of the central issues of the life sciences. Stories from membrane research challenge distinctions such as those between the living and unenlivened, or the "natural" and the "synthetic." (32)

Grote emphasizes, of course, that contemporary material modeling focuses on biomolecules, and that is in some way different than the discussion of organs as machine-like that began in early modern philosophy (and is in some ways carried over in thinkers like Polanyi).

The discussion of membrane sciences here focuses detailed attention on what Grote dubs "chemical thinking and working," which addresses "isolation,

preparation, making, and reassembling matter" (33). He shows how different threads of research came to be connected and how work on "membrane transport" (41) helped draw things together early. The "machine analogy" became more than analogical since it came to "'reconstitute' biochemical reactions" (51). Subsequently, in the 1980s, "novel methods" were developed through which membrane proteins could be isolated biochemically and "material models" (56) of membrane processes could be emulated in a test tube. Thus a model of membrane organization as a mosaic emerged. Grote chronicles the key discovery of bacteriorhodopsin (BP) as an ideal (colored) membrane protein for research. He shows how some areas of basic biological inquiry became more reliant on "chemical practices" and thus became more about materials in test tubes that could be "de- and recomposed or modified"; the "transformed materiality of biological matter" shaped the now predominant "contemporary molecular-mechanical vision" (115).

Grote shows how, as components of life became modules of material substances, researchers "acquired an arsenal of living substances that is synthetic in many ways" (113), which they could manipulate:

> Produced by genetically engineered organisms or made by automats assembling molecules, modified by attaching tags or probes to it, and finally assembled into a cell-like structure that can be researched in a "plug and play" mode. (113)

"Chemical molecular biologists" in work on "biological macromolecules" (135) made them entities that can be made and remade by human beings. "Man-made, hybrid and mobile chemical substances are recognized as 'synthetic' by 'protein engineering'" (139). The "materiality of life" (114) in biological science late in the twentieth century thus became something fundamentally different than it was in the middle of the century. As Grote provocatively puts matters, using a German term for "material substance" (187), there was a "transformation of life's material inventory from Stoff of nature toward Stoff of the laboratory…." This transformation is the "hallmark of the present molecular life science" where "research on life is caried out widely in the 'plug and play' mode" (116).

Grote's final chapter turns to a review of what he dubs the "visionary, alternative and radical aspects" (169) of biotech in the eighties. Some of the projects on biochips and nanotechnology, sometimes projects tied up with speculative capital, seem not to have produced much other than speculation, although membrane science seems to lie behind this in the deep background. Grote comments, at the end of his book, on the personas of most of the major players in the development of the molecular-mechanical vision:

> Most of those encountered in this story stayed faithful to small-scale science in academic institutions, nobody turned into a public intellectual dabbling in philosophy or politics, and the degree of self-historicization in this field has been negligible if compared to molecular biology, recombinant DNA or the Human Genome Project (205).

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