

**Maria Şerban, Sara Green**

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# Why the Small Things in Life Matter: Philosophy of Biology from the Microbial Perspective

Maria Şerban and Sara Green\*

Maureen A. O'Malley, *Philosophy of Microbiology*. Cambridge: Cambridge University Press (2014), x+269 pp., \$30.39 (paper).

## Introduction

There is plenty of room at the bottom. (Richard Feynman)

And it is not only for physicists. In her book, *Philosophy of Microbiology*, Maureen O'Malley invites philosophers of biology to look more closely and more intensely at the lessons that microbes can teach them. Even those who are not easily impressed by the scientific venues that this book ventures into cannot remain entirely immune to the breadth of debates and questions, both current and historical, that the book addresses in less than 280 pages. O'Malley's daring hypothesis is that looking "at the bottom" may not only hold important answers to vexing philosophical questions but also lead to the reorientation of philosophical discussions and to the reconceptualization of central topics in biology. A general lesson of the book is that it matters not only what (philosophical) questions we are asking but also where we are looking for the answers.

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\*To contact the authors, please write to: Maria Şerban, Center for Philosophy of Natural and Social Science, London School of Economics and Political Science, 7 Portugal Street, WC2A 2HJ London; e-mail: mathlog@gmail.com. Sara Green, Department of Science Education, University of Copenhagen, Øster Voldgade 3, 1350 Copenhagen K; e-mail: sara.green@ind.ku.dk.

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The six main chapters of the book construct a case for taking seriously the littlest of the living things: microbes. O'Malley weaves four fresh perspectives into the arguments of the book in support of her general case for the philosophical relevance of a microbial focus: biodiversity, biogeochemistry, evolutionary history, and symbiotic collaboration. The philosophical and scientific debates surveyed in the book span a variety of topics that are carefully knit into the fabric of the book, with various threads running through several chapters. In this review, we focus on one major theme that resurfaces at various points in the dialectic of the book connecting the arguments presented in all six chapters: microbes as model systems within biology itself and for philosophical accounts of biology-related topics. Emphasizing model systems allows us to assess two important claims that O'Malley makes about the impact of a microbial focus on broader philosophical questions such as "What is life?" "What is the unit of evolution?" or "How are biological organisms organized?" and on philosophical methodology in general.

**Microbes as Model Systems.** O'Malley shows how both historical and contemporary perspectives on the field of biology support the idea that microbes are one of the main entry points into the study of many different aspects of the functioning, organization, and evolution of biological organisms. She highlights two features of microbial systems that are responsible for their widespread use: their experimental tractability and their capacity to represent various properties or processes observed in all forms of life. More concretely, she points out that a host of theoretical accounts developed in genomics, systems biology, and molecular biology, as well as experimental approaches to evolution and ecology, are premised on the assumption that microbes exhibit general features of molecular structure and function, reproduction, variation, heritability, and fitness that characterize all forms of life.

Drawing mainly on practice-driven observations, O'Malley's book constructs a multifaceted argument for why philosophical accounts that typically take humans or other multicellular organisms as their starting point should pay more attention to microbes. Perhaps the strongest claim in the book is that microbes are superior to macrobes when it comes to illuminating philosophical analyses of topics such as biological classification, evolution, ecology, or the nature of life itself. This claim is not premised on any strong assumptions about the "unity of life" or about microbes being general "elementary particles" for biological accounts. Rather, O'Malley shows that a careful study of the scientific practices reveals the importance of microbes for almost all biological research and argues that a shift of focus to microorganisms can be (constructively) disruptive to many assumptions that philosophers of science have long taken for granted. The book thereby calls for a more reflective choice of model systems on which philosophers base their conceptual accounts. We find her strategy particularly interesting

because it pushes philosophy to play a more engaged role in substantial debates that arise within microbiology itself (and potentially in other fields of biology as well).

We understand O'Malley's strategy as a *divide et impera* and "bottom-up" approach that consists in identifying and evaluating the distinct epistemic roles that microbial model systems play in different investigative contexts (e.g., evidential support, prediction, control, representation, unification, explanation). This approach makes it more concrete what philosophical analysis can bring to the table: a critical and comparative survey of the variety of epistemological functions that microbial model systems can play (and have played) in biological theorizing and experimenting. Moreover, O'Malley argues that such a philosophical analysis can be truly informative only if it draws on the lessons afforded by both the successes and the failures of using microbial systems in biological research. We mention here some of the most interesting cases.

Experimental evolutionary biology is one field in which microbes play a key role in testing causal hypotheses about different evolutionary scenarios. Stimulated by the inspiring work of Richard Lenski on tens of thousands of generations of *E. coli*, experimentation on microbial model systems has developed over the years into a powerful method that can corroborate, extend, and sometimes challenge theoretical hypotheses about evolutionary processes otherwise supported by the comparative method and historical narratives. In addition to this evidential role, O'Malley suggests that these experimental scenarios can have an even deeper impact in sharpening or modifying our understanding of broad general features of biological phenomena such as evolvability, hypermutation, the interplay of neutral to adaptive evolutionary processes, convergence, and kin selection. Chapters 1, 4, and 6 explore these conceptual changes in some detail, although often the arguments function as "hooks" that draw the reader into the search for a deeper understanding of the dynamics of these biological ideas.

O'Malley's discussion of models of evolutionary transition provides another occasion to explore the diversity of epistemic roles of model microbial systems. Whereas approaches to evolution starting with animals or plants typically emphasize a hierarchical view of evolution with increasing complexity over time, this hierarchy looks much "flatter" in light of microbial diversification (cf. Sterelny 1999). Similarly, the evidence in support of lateral gene transfer and endosymbiosis in microbial cultures questions the basis for seeing single lineages as units for selection and draws attention to the consequences of adopting the "tree of life" metaphor and to the importance of multilineage collaboration in evolution. This supports the idea that microbes as model systems can play an inferential role at a quite abstract level of biological theories, proving the plausibility of alternative theoretical conceptions of evolvability, sociality, multicellularity, and communication.

A quite different epistemic role for microbes in biological research is illustrated by the success of yeast experiments in evolving multicellularity *in vitro* (Ratcliff et al. 2012), a case discussed at length in chapter 6. Following Levy and Curie (2014), O'Malley suggests that in these investigative contexts microbial systems represent a paradigmatic case of modeling because they are used as "surrogates for a general process, rather than to make empirical extrapolations to related organisms" (O'Malley, 184). In other words, the types of inferences drawn in these contexts are not mere empirical generalizations because they do not exploit analogies between particular (pairs of) systems but rather abstract away from the experimental microbial case to hypothesize general principles that occur in a wide variety of systems. However, the discussions of these issues in chapter 6 works more like a teaser for future debates concerning the epistemic roles of microbial model organisms.

O'Malley dedicates a more extensive analysis to the heuristic role of microbial model organisms. She argues that as experimental models, microbial systems can be used to show what biological patterns or phenomena are possible and how they come about (cf. Dykhuizen and Davies 1980). In this function, O'Malley argues that microbial systems work as intermediaries between mathematical models and field observations, sharing features with both types of epistemic constructions. The list of examples of successful uses of microbial model systems that exhibit this function include bacterial chemotactic research, social evolution, and the investigation of different principles of cognition (cf. O'Malley, 184–89). More provocatively, O'Malley suggests that the heuristic role of model microorganisms warrants some degree of continuity between these different areas of research. In this, she follows the proposal of the early molecular approaches to bacterial chemotaxis that conceived this phenomenon as an entry point to the study of sensory behavior and even to neurobiology and psychology (e.g., Adler 1966). Alas, for those expecting a more concrete proposal emerging from these claims, O'Malley provides no more than a bold invitation at considering how these themes might be further connected with debates in other areas of science and philosophy (e.g., philosophy of mind and cognitive neuroscience). This line of argument nevertheless has some constructive implications concerning questions about philosophical methodology to which we will return below.

**Life.** How do these different epistemic roles of microbial model organisms shape our philosophical analysis of general concepts such as biological organization, function, and life? At the most general level, the assumption that microbes (have features that) are representative of all forms of life supports a continuity of life perspective that in turn justifies the study of the organization and functioning of living things within shared scientific frame-

works. Can this perspective also make room for understanding the major differences between diverse forms of life? O'Malley argues that it does and that focusing on microbes as objects of biological investigation does not privilege any unique hierarchy of living things. In particular, she stresses that philosophy of microbiology can help correct some of the dangerous consequences of adopting a human-centered view of life blindly. O'Malley shows that microbiology can offer a fresh perspective on classical discussions of the nature of life in at least two ways: by reorienting questions concerning the origin of life to current research inspired by microbiological theories and by challenging the dominant methodological individualism that tends to place bigger organisms at the center of our reflections about the nature of life.

More specifically, attention to microbes results in blurring many of the boundaries that are typically taken for granted, even when it comes to what an organism or a human body is. The study of microbes brings out the collaborative nature of metabolism in a variety of systems, for example, how human gut bacteria are intrinsic to human health and how multilineage collectives make up important parts of ecosystems. This community orientation with emphasis on collaboration feeds back into philosophical discussions of life in which autonomy is typically taken to be a central defining feature of life (see also Dupré and O'Malley 2009). The increased focus on metabolism and metagenomics for understanding life and evolution also brings (back) biochemistry to the center of philosophical debates in which molecular biology and evolutionary biology recently have been the main "model fields."

The discussion of the concept of life illustrates a more general moral of O'Malley's book, namely, that microbiology has the potential to bring to the philosophical scene a set of new perspectives and questions that challenge our received ways of thinking about central notions in biology. In addition to the promise of conceptual clarification, the analyses sparked by microbiological research can have important social and cultural implications on how we think about the organization of scientific disciplines, their impact on conservational policies, and our general way of conceiving our place in the living world.

**Methodology.** O'Malley explicitly follows what Turner (2011) calls a "science-first" or "bottom-up" methodology and acknowledges the difficulties for this approach of going beyond a descriptive reiteration of scientific practice. The cautious route taken in this book will probably be unsatisfactory to some readers who are expecting to find elaborate theses about how specific philosophical accounts would look like from a microbial perspective. Yet, it is important to note that this practice-oriented approach has important complementary virtues to a philosophy-first methodology. O'Mal-

ley's aim is to open a whole new research field in philosophy of science by showing how microbiology can breathe new life into both biological and philosophical debates. The book also has profound metaphilosophical implications. The author calls for a reflection among philosophers on their choices of "model organisms" or "model fields" when developing their accounts of living systems or of biological research practice. In this sense, starting with the scientific practice has normative implications for philosophical methodology itself. O'Malley shows how some of the most basic assumptions of philosophical classifications can be questioned by looking "at the bottom." Avoiding the inertia of received ideas and unquestioned assumptions (no matter from what field of inquiry they originate) should be the continuous and perpetual task of any philosophical enterprise, and the *Philosophy of Microbiology* is a compelling reminder of this.

Another important methodological stance taken in the book concerns the positioning of the philosophy of microbiology with respect to philosophy of biology and philosophy of science more generally. O'Malley claims that philosophy of microbiology can act as the middle man between these two fields, and the book exemplifies how it is possible to discuss philosophical topics in a way that is more accessible to a scientific audience.

This brings us to the question of who is the intended audience of this book. We think that, despite its sometimes technical biological language, the book is approachable to a wide audience on both sides of the philosophical/scientific divide. In fact, the book can be read as an effort to bridge what might well be an imaginary gap between the two areas of inquiry, showing that wonder and the commitment to try various exploratory strategies to unlocking the mysteries of nature is the common source of these two broad enterprises.

**Conclusion.** We think that the debates surveyed in O'Malley's book afford important lessons about modeling and explanation in microbiology that can be extended to other fields of investigation as well. The book leaves open lots of the questions it raises, while the main role of its author is to guide the reader in seeing as clearly as possible the various perspectives available to her. We see this as an open invitation to participate in the discussion of the numerous topics that *Philosophy of Microbiology* ventures into.

Focusing on the very small, Maureen O'Malley's book opens up a large space of conceptual possibilities available to both philosophers and scientists alike. The author convinces us that microbes can no longer be "the invisible elephant in the room" since that puts us in the dangerous epistemic position of missing out on an exciting world of knowledge and on very valuable tools for refining our philosophical and scientific views of the biological realm.

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