Review of Robert W. Batterman's *A Middle Way: A Non-Fundamental Approach to Many-Body Physics*

Robert W. Batterman, *A Middle Way: A Non-Fundamental Approach to Many-Body Physics*. New York: Oxford University Press (2021), 174 pp. $74 (hardcover).

Robert W. Batterman's *A Middle Way: A Non-Fundamental Approach to Many-Body Physics* is an extraordinarily insightful book, far-reaching in its scope and significance, interdisciplinary in character due to connections made between physics, materials science and engineering, and biology, and groundbreaking in the sense that it reflects on important scientific domains that are mostly absent from current literature. The book presents a hydrodynamic methodology, which Batterman explains is pervasive in science, for studying many-body systems as diverse as gases, fluids, and composite materials like wood, steel, and bone. Following Batterman, I will call said methodology the *middle-out strategy*. Batterman's main thesis is that the middle-out strategy is superior to alternatives, solves an important autonomy problem, and, consequently, implies that certain mesoscale structures (explained below) ought to be considered natural kinds. In what follows, I unpack and flesh out these claims, starting with a discussion of the levels of reality and its representation. Afterward, I briefly outline the contents of the book's chapters and then identify issues that seem to me to merit further clarification. Last, I outline an application of the middle-out strategy for the realism debate.[1]

To start, it is helpful to think about systems and their description at three different scales. There is the *macroscopic scale* of everyday objects that are considered homogenous and are described "top-down" by "non-fundamental" theories like thermodynamics and fluid mechanics, and by laws such as the thermodynamic equations of state, the Navier–Stokes equations (for fluids), and the Navier–Cauchy equations (for solids). The continuum description of macroscale objects and systems is an idealization of sorts. For example, a dilute solution of sugar (the solute) in water (the solvent) may be treated as a fictional homogeneous blob. Of course, in reality, the water–sugar solution is composed of molecules. Accordingly, there is the *microscopic scale* of atoms and molecules in which systems are considered heterogenous and are represented "bottom-up" by "fundamental" theories like molecular dynamics and classical statistical mechanics, or quantum theory. Microscale descriptions of systems are considered approximately true and accurate.

In addition, there is a third *mesoscopic scale* described by "intermediate theory" appearing in contexts such as condensed matter physics, materials science and engineering, and biological modeling. For instance, said dilute (water–sugar) solution viewed at the mesoscale will contain corpuscular sugar molecules (undergoing Brownian motion) while suspended in a solvent fluid. Generally, objects inhabiting the mesoscale may be characterized by representative volume elements (RVEs),

---

[1] All citations are from *A Middle Way*, and use of quotation marks without page numbers signifies terms that arise throughout the book.

which are statically representative of features (of a system of interest) at some particular spatial scale. Such features include the geometric shapes and topology of RVEs that are described by "correlation functions" (in space and time), which characterize "material parameters" like Young's modulus (describing bending, stretching, and deforming behaviors). Correlation functions also characterize "order parameters" like the net magnetization of a ferromagnet in which individual (atomic) spins are correlated with each other such that regions of spin-up and spin-down are formed at the mesoscale. Let us call RVEs, and material and order parameters, "mesoscale structures." Importantly, there is no one mesoscale, because what counts as a mesoscale structure depends on the problem or system at hand.

Macroscopic many-body systems like fluids exhibit bulk properties and regularities, patterns of behavior that are "repeatable, relatively stable [phenomena]" (31). Such regularities, namely, "certain dominant, *lawful* behaviors," are well represented by, for example, the Navier–Stokes equations in the sense that macroscale theories are relatively autonomous from microscale theories and details (121). One can study such systems solely from a top-down approach and maintain "full-on emergence [regarding said behaviors] characterized by the complete autonomy of the emergent theory from the more fundamental theory" (147). Alternatively, one can approach many-body systems from the bottom-up with "direct reductionist connections" or "reductionist upscaling" from the microscale to the macroscale, such as when macroscopic temperature is characterized as the mean kinetic energy of microscopic particles. Batterman holds that both methods are, generally, misguided. Instead, he proposes the middle-out strategy to upscaling, which appeals to mesoscale structures to mediate between the microscale and the macroscale.

The middle-out strategy is superior to said alternative strategies for at least two reasons. First, mesoscale structures are "better able to figure in explanations, [and] better able to provide descriptions and understanding of [said macroscale] behaviors," as well as allowing for "much more effective modeling of mesoscale regularities" (121). Second, "they also provide the best explanation for why continuum-scale regularities hold" (121). Specifically, by appealing to mesoscale structures, the middle-out strategy affords an answer to the following question (hereinafter AUT) about autonomy: "How can systems that are heterogeneous at some (typically) micro-scale exhibit the same pattern of behavior at the macro-scale?" (31). In particular, the fluctuation–dissipation theorem entails that mesoscale structures will be needed for answering AUT and understanding interscale and theoretic relations. Next, Batterman expounds,

> If we can show that … macroscopic behavior is stable under the perturbation of the molecule details of one [system] into those of another, then we have shown that those *molecular details are* essentially *irrelevant* for that macroscopic behavior . . . . An alternative way to think about answering (AUT) is … to show, for an individual system that is heterogeneous at some lower-scale, that we can find an equivalent homogenous system—one that displays the same behavior at continuum scales . . . . [If] we find a system that displays no structure at any scale, but that also exhibits the same behavior as the actual heterogenous system … then we know that the upper-scale behavior can be characterized without referencing any actual lower-scale details. Here too, we will have shown that *molecular/atomic details are irrelevant*. (140, emphasis added)

The two senses of superiority noted, along with the metaphysical significance of the fluctuation–dissipation theorem, have the added consequence that mesoscale structures are natural kinds because they are “the natural or the *right* variables” for describing many-body systems and their bulk behaviors at the mesoscale and macroscale (145, emphasis original). Thus, by attending to the mesoscale, which is a midway between the macroscale and microscale, and focusing on the scientific and theoretical for taking mesoscale structures to be natural or right, we find a middle way between a “full-fledged normatively relativized notion” of natural kinds and metaphysical notions. The former relativizes natural kinds to the goals of scientific inquiry, such as causal representation and explanation, whereas the latter holds that they are the variables appearing in fundamental (namely, microscale) theories (123–25).

Chapter 1 introduces the reader to the middle-out strategy and the various senses in which Batterman advocates for a middle way (similar to my own, preceding description). It also includes a helpful preview of the book’s chapters. AUT is presented in chapter 2 as the real challenge posed by the possibility of multiple realizability, and solutions provided by the middle-out strategy are outlined. The middle-out strategy, in fact, is widespread because the emphasis on mesoscale structures arises in prima facie different domains. One such domain, discussed in chapter 3, concerns order parameters and the hydrodynamic description of many-body systems, as well as an equivalent description with correlation functions, where such equivalence is a consequence of the fluctuation–dissipation theorem (along with other considerations like Onsager’s hypothesis). It is exemplified, in chapter 4, in Einstein’s work on Brownian motion, where the size of molecules of a solute can be derived from two considerations: the change in viscosity of a solvent due to the addition of the solute (e.g., such as when dissolving sugar in water) and the rate of diffusion of the solute in the solvent. The latter consideration is the first instance of what later became known as the fluctuation–dissipation theorem. A second domain, examined in chapters 5 and 6, includes materials science and engineering and concerns the earlier noted RVEs and material parameters. Chapter 5 in particular illustrates how the first (hydrodynamic) strategy is relevantly analogous to the second (materials science and engineering) strategy, whereas chapter 6 applies the second strategy to biological modeling of bones. In addition, chapter 6 highlights the necessity of treating order and material parameters as mesoscale variables that are essential for understanding intertheory relations between microscale and macroscale theories. The consequence that mesoscale structures are natural kinds is drawn in chapter 7, and chapter 8 ends the book with a summary of the main conclusions.

A Middle Way represents research in the history and philosophy of science par excellence and will no doubt guide important future work in philosophy of physics and science. Still, two issues seem to me to merit further clarification. First, how are we to understand the thesis that mesoscale structures are natural kinds? One interpretation, consistent with Batterman’s claim that the middle-out strategy supports a middle way between normatively relativized and metaphysical notions of natural kinds, is that he is advocating a kind of scale-relative ontology, as in Ladyman and Ross’s (2007) *Every Thing Must Go* and Shech and McGivern’s (2021) “Fundamentality, Scale, and the Fractional Quantum Hall Effect.” Perhaps one could appeal to Ladyman and Ross’s account of “real patterns” as nonredundant projectible regularities to argue that mesoscale structures are genuine entities. Redundancy here may be understood dynamically because the middle-out strategy greatly simplifies the dynamics of systems of interest compared with microscale descriptions. However, Batterman also says that “the degree of naturalness of a variable is proportional to the variable’s ability to aid in accounting for” the relative autonomy of macroscale theories from microscale theories, thereby suggesting a notion of natural kinds that is normatively relativized to answering AUT (120).

Second, Batterman holds that an in-principle derivation from microscale theories of the same macroscale behavior, for two different systems that are heterogeneous at the microscale, does not answer AUT (32). Yet, reflecting on the passage quoted at length earlier, the key to explaining AUT consisted of showing that micro details are *irrelevant* to macro behavior, and this is what is shown when one derives the same macro behavior from different systems described by microscale details and theories. Anticipating such a response, Batterman explains that “this misses the key aspect of the question (AUT); namely, that we are interested in *understanding what is responsible for the robustness or stability* of the macro-scale” (33, emphasis original). It isn’t clear, though, how the middle-out strategy provides such understanding beyond what would be attained with in-principle derivations from microscale theories. Afterall, systems that are as distinct on the microlevel as, say, iron and aluminum manifest common macroscopic behaviors, such as abiding by, say, Newtonian laws of motion and gravitation (assuming everyday scales), and yet no appeal to the middle-out strategy seems viable to explain such common behaviors. Is AUT irrelevant in this context, or is the middle-out strategy applicable? If neither, and if in this case one can explain AUT by appealing to a Newtonian limit of relativity theory (see Fletcher 2019), why do such explanations not extend to contexts where the middle-out strategy is viable?

Last, by affording a novel explanation of AUT, the middle-out strategy allows us to “understand the remarkable fact that … continuum theories survived the atomic revolution despite being ontologically inaccurate” (x); it accounts “*for the success of our phenomenological theories*” (35, emphasis original). This suggests an application to the scientific realism–instrumentalism debate. On the side of instrumentalism, the middle-out strategy shows that explanatory and predictive success of (macroscale) theories can be had without truth (about microscale ontology), in contrast to the realist’s claim that truth best explains success. This may suggest an extension to antirealism about other scales as well. On the side of realism, the middle-out strategy appeals to microscale entities (e.g., individual spins) and mesoscale structures (e.g., regions of spin-up and spin-down/RVEs) to ground the autonomy of the macroscale bulk properties and behaviors. If, further, mesoscale structures are natural kinds, then realists may champion the middle-out strategy for their cause.

Elay Shech
Auburn University, Auburn, AL, USA
Email: eshech@auburn.edu

References

Fletcher, Samuel C. 2019. On the Reduction of General Relativity to Newtonian Gravitation. *Studies in History and Philosophy of Science, Part B* 68:1–15.

Ladyman, James, and Don Ross, with David Spurrett and John Collier. 2007. *Every Thing Must Go: Metaphysics Naturalized*. Oxford: Oxford University Press.

Shech, Elay, and Patrick McGivern. 2021. “Fundamentality, Scale, and the Fractional Quantum Hall Effect.” *Erkenntnis* 86:1411–30.