ONE

Introduction: Active Matter—Some Initial Philosophical Considerations

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Abstract

In the near absence of discussion of conservation by philosophers, this chapter addresses two fundamental philosophical questions underlying Conserving Active Matter. The first is conceptual, the second normative. First, in considering what active matter might be in terms of a viable concept, it identifies two possible views: a taxonomic view, proposing distinctions among types of matter in relation to activity, and a spectral view that conceives of active matter as being at one end of a set of continua pertaining to reactive matter. Second, this chapter poses a series of questions about normative considerations of active matter. These include the following: When is material change something to resist or repair, and when is it something to embrace and facilitate? On what bases and according to what norms can those responsible for material things make these determinations? The purpose of this chapter is not to advance any determinative theory concerning active matter and conservation, but simply to serve as a prolegomenon offering an initial map of the terrain in philosophically consistent terms.

> Ah! how hard a thing it is to tell what a wild,
> and rough, and stubborn wood this was, which
> in my thought renews the fear!
> —Dante, *Inferno*, 1:4–6

Two philosophical questions lie at the heart of the Conserving Active Matter research project. First: What is *active matter*? Second: Under what conditions is active matter something to value or disvalue? Like all

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philosophical questions, these do not have definite, or even straightforward, answers. Accordingly, we could not hope to answer them in this brief introductory chapter. Instead, we set out to map the conceptual terrain in which these questions are located with the hope of offering routes through the dark wood.

We begin with an attempt to sharpen the very concept of active matter. First, we acknowledge some of the various stipulative definitions used by scientists, and, second, we compare and contrast active matter with neighboring concepts involving material change. We then explore the various kinds of change of which matter is capable. This investigation will be part conceptual, part empirical. We then turn to some central normative questions: When is matter's activity something to resist or repair, and when is this activity something to embrace and perhaps even facilitate? Again, our aim will not be to provide answers but, rather, to sharpen the questions and set the stage for contributions by four fellow philosophers: Sherri Irvin, Carolyn Korsmeyer, Alva Noë, and Yuriko Saito.

Active Matter As Concept

The term "active matter" is used by some scientists, technologists, and designers in a variety of sometimes overlapping senses. For instance,

> Active matter describes systems whose constituent elements consume energy and are thus out-of-equilibrium. Examples include flocks or herds of animals, collections of cells, and components of the cellular cytoskeleton. When these objects interact with each other, collective behavior can emerge that is unlike anything possible with an equilibrium system.[1]

In other usage, the term can apply to "physical materials that can assemble themselves, transform autonomously, and sense, react, or compute based on internal and external information."[2] Introducing a journal issue devoted to active matter, two physicists and a biomedical engineer state, "Active matter includes living and non-living systems that have in common that they contain energy-consuming and force-generating microscopic constituents that drive emergent dynamic properties on larger scales."[3] Our discussion of active matter is responsive to, but is not constrained by, these and other doubtless locally useful stipulative definitions.

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Our own discussion begins with the less controversial component of the conceptual dyad: matter. We take matter to be constituted of atomic particles, either independently (in the case of elements) or in molecular combinations. Matter is that which occupies space. Since the seventeenth century, philosophers have commonly captured this notion with the concept *extension*. Matter is that which is extended.[4]

But what does it mean to say that matter is, or could be, active? We identify two conceptually distinct yet promising approaches to this question: a taxonomic view of active matter and a spectral view of active matter. As we explain below, on a taxonomic view, active matter is but one species of a broader category of *changing matter*; whereas on a spectral view, active matter lies at one end of a complex continuum of *reactive matter*.[5]

First, we propose a taxonomic view of active matter, where active matter is distinct, or mostly distinct, from other subsets of changing matter, where "changing" means a progressive difference in a thing's material features.[6] These other subsets include, but are not limited to, *passive* and *reactive matter*. Passive matter would be matter subject to change without responding or initiating action in return, for example, a lump of damp clay subject to changes in form by manipulation owing to its malleability or ductility. In the case of reactive matter, an external stimulus is the motor of change, but in this case the reactive matter participates in the change, as in the case of reagents added to a system to bring about, or test for, a chemical reaction, one example being hydrochloric acid when used in the industrial production of polyvinyl chloride (PVC), a common synthetic plastic polymer.

Following this line of thinking, *activity* connotes a thing's direct participation in its own processes of change. We might, then, think of active matter as matter capable of spontaneous change in the sense of *self-generating* and not dependent on any external stimulus. Spontaneous change can be of three kinds—which, by the way, also apply to the spectral view of active matter, to be discussed below. One is change that leads to replication, proliferation, or the emergence of new constituents of the matter concerned. The second is change that is self-consuming, whereby matter feeds upon itself degeneratively, leading eventually to dissolution. The third is nondirectional, or random. Living matter is an example of matter subject to the first kind of change. Stars, including our own sun, are an example of the second kind. An example of random change is the process of change that underlies evolution, however directional it may appear in hindsight. Let us look more closely at the first kind.

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Although living matter may be active matter in a broad sense, one assumption motivating this project is that there exists a kind of directional active matter that is nonliving in the biological sense. This biologically nonliving active matter is what we shall discuss henceforth as "generative active matter." When considering this together with degenerative active matter and random active matter, we shall use the term "active matter" without qualification.

Defining living matter is itself a topic of considerable contention within both philosophy and biology. Biologist Radu Popa, for instance, offers three hundred or so definitions of life.[7] Whatever living matter might be, generative active matter, in contradistinction to it, comprises things other than entities that are capable of "self-reproduction with variations," as biologist Edward Trifonov has defined life.[8] The key thought here is that generative active matter is biologically nonliving but active in the sense that the changes it exhibits are not generated externally by other factors, whether physical or chemical, acting upon it.

Active matter on the taxonomic view—whether generative, degenerative, or random—excludes biologically living matter but may include matter that is living in other senses. These include being animate or endowed with personhood. We refer here to living things recognized as such in the knowledge systems of peoples other than those of the European diaspora. Our colleagues discuss examples in this volume and elsewhere in this project under the rubric "Indigenous ontologies."

We are hard-pressed to identify matter that is generatively or randomly active, but nonliving in the biological sense. What could this self-generating changing stuff be? Candidates might be the fabric MycoTEX, produced from fungal mycelium by Dutch clothing designer Aniela Hoitink and her company, NEFFA, or the "programmable water-based biocomposites for digital design and fabrication across scales" named Aguahoja, produced by the Mediated Matter research group at the Massachusetts Institute of Technology led by founder and associate professor of media arts and sciences, Neri Oxman.[9] Yet neither MycoTEX nor Aguahoja appears to be self-generating beyond the bounds of life. Generative active matter, in the sense we have defined it, would seem, at present, to be conceptual but not yet actual matter.

In contrast, *changing matter* that spontaneously degenerates appears to exist in actuality. It is of two kinds. The first, an example of which is the sun, is self-contained but complex, comprising numerous constituents that react with one another whether chemically or

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in nuclear and physical senses. The second kind of degenerative active matter is simple, as in the case of the unstable isotopes of single elements that undergo spontaneous nuclear decay. We shall say more about isotopes below.

Thus far we have been talking about active matter on the taxonomic view, but there is another way to think of it, namely, a spectral view that conceives of active matter as being at one end of a set of continua pertaining to reactive matter. These continua include, but are not invariably confined to, the extent of change, the rate of change, and the frequency of change. Our idea is that reactive matter admits of degrees along these and other lines and that a spectral view reserves active matter to describe not a distinct species of matter that differs in kind from others, but for matter that, for example, reacts often and quickly and changes dramatically.

We do not mean to suggest that these continua apply only to active matter on the spectral view. Active matter conceived as a taxon of changing matter also admits of degrees: active matter, like its neighbors passive and reactive matter, can change more or less quickly, more or less dramatically, and so on. But on the taxonomic view, these variables are not characteristic of the taxon, whereas on the spectral view, it is precisely the degree of change along these various continua that characterizes active matter.

We have just discussed extent of change, rate of change, and frequency of change as variables applying to changing matter. Earlier, when considering the taxonomic view, we examined another variable, namely, *direction of change*. We shall now return to direction of change, and also add remarks on regularity of change. Direction of change encompasses movement toward a given state, such as generative changes including growth and development, and movement away from a given state, such as degenerative changes, for instance, decay and deterioration. Direction of change also encompasses change that is not directed toward any state in particular, such as change that is random. *Regularity of change* encompasses change that is consistent and predictable, or irregular, stochastic, and unpredictable. Some processes of material change can exhibit aspects both regular and irregular, as in the formation of microscopic crystals when chlorides in the patina of copper-containing alloys interact with oxygen and water to produce the condition known as bronze disease. All these variables—extent of change, rate of change, frequency of change, direction of change, and regularity of change—admit of degrees and cut across both the taxonomic and spectral views of material change.

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This map of the conceptual terrain accounts for what we take to be the principal ways of thinking about how matter changes. But how do these conceptual possibilities meet, or fail to meet, the empirical world? How exactly does changing matter in our known world actually change? Of course, a full discussion of actual material change is not best addressed by philosophers, but no discussion of this issue would be complete without a brief exposition of how changing matter actually undergoes change. We leave it to scientists and others who deal with actual changing matter to determine whether the empirical world inclines us toward a taxonomic understanding of material change or toward a spectral one.

Scientists usually speak of three basic types of change to matter: chemical, physical, and nuclear. Chemical change occurs when atoms and molecules interact—bond or rebond—to form new materials. A change is physical when the matter subject to change retains its underlying atomic or molecular identity. Nuclear change is a change in nuclear structure, which occurs when an atomic nucleus splits (fission), when two or more nuclei combine (fusion), or when an unstable nucleus loses energy by radiation. Many physical changes can be easily reversed, whereas chemical and nuclear changes either cannot be reversed or cannot be reversed without extraordinary effort. A shift in the energy environment of matter can bring about physical or nuclear change, as in the case of exposure of matter to radiation in the form of waves or subatomic particles, or the collision of subatomic particles. A shift in the energy environment can result in changes in the *state* of matter.

Matter exists in a variety of states. Matter has likely existed, can actually exist, and might theoretically exist in over twenty states, but we draw attention to those four that most people experience in everyday life: solids, liquids, gases, and plasmas. External conditions affect the state of any given matter. H_2O (water) can freeze to form solid ice yet remain the same in chemical terms as when it was liquid. Ice and water are two states of H_2O.[10]

A specific type of nuclear change is isotopic. Elements—matter not reduceable to further massive atomic constituents—exist in a variety of isotopes. An isotope is a form of an element that contains the same number of protons as other forms of the same element but that has a different number of neutrons in its nucleus. Therefore, each isotope of any given element differs from other isotopes of the same element in relative atomic mass but not in chemical properties. There are, for instance, seventy known possible isotopes of gold, only one of which, ^{197}Au, can be counted stable in any practical sense. The radioisotopes of gold decay at various rates, with half-lives ranging from 300 nanoseconds to 186 days, though they invariably retain seventy-nine protons in each of their atomic nuclei.[11]

Whatever the changes any matter undergoes—whether chemical, physical, or nuclear—that matter is perpetually, actually, or potentially changing. We would be hard pressed to identify any matter in the actual known universe that is perfectly static, which means that material stasis is a mere conceptual possibility, which is worth entertaining insofar as it may help us to find a route through the dark wood.

Normative Considerations

We have just been outlining various conceptual possibilities for understanding what active matter is. We now turn to explicitly normative questions. We consider there to be three sets of questions of particular relevance. We shall do no more than mention two of them, and then give greater attention to the third.

First, What is the relationship between the values or disvalues placed on material change, on the one hand, and the directionality often attributed to change (as we discussed in the first section above), on the other? Is to attribute a direction or telos to material change already to value or disvalue it, at least implicitly?

Second, Can aging and degradation improve a material thing, and if so, under what conditions? What sort of improvement might this be, for instance, aesthetic, practical, or ethical? What might the implications of such questions be for conservation and other institutionalized forms of practice?[12]

Our third set of questions will be the focus of the rest of this chapter. As in the previous section, our aim is not to provide answers but instead to sharpen the questions, thereby setting the stage for the contributions by Sherri Irvin, Carolyn Korsmeyer, Alva Noë, and Yuriko Saito. These questions include the following: When is material change, however conceived, something to resist or repair, and when is it something to embrace and perhaps even facilitate? On what bases and according to what norms can those responsible for material things make these determinations? What value do some communities find in an ideal of material stasis? Why do these communities take elaborate pains to try to ensure material stasis through preservation, restoration, and conservation? What value do some communities find in material

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change, even change understood as degradation and decay? Why do they lend privilege to things that have changed or that continue to change? And when some communities ascribe to both of these values in respect of different things or, in some instances, even of the same things, what are the bases for these differentiations? Are there reasons aesthetic, practical, ethical, or some combination of these, or other reasons entirely?

We refer to *communities* in order to foreground the fact that various peoples at various times and in various places have valued material change or material stasis for a variety of reasons and often in markedly different ways. We mean community as an elastic concept that can encompass groups as diverse as practitioners of Japanese tea ceremony, European romantic poets with a love of ruins, Māori guardians of living *taonga* (treasured ancestral items), and the international community of professional conservators.

Let us proceed by briefly exploring aspects of this last example. The practice of object conservation has long had material stasis as its overarching ideal. This means that the fundamental condition of matter—namely, its inevitable susceptibility to some degree of change—provides the central challenge that all professional conservators face. Especially, though not exclusively, the ideal for items in museum collections is that they should be preserved in perpetuity. In museums, perpetuity is a value with broader applications than to collections alone. Donors' lawyers often insist that the terms of a gift to a museum, whether of funds or of objects, should ensure the public acknowledgment of the donor's act in perpetuity. No parties involved believe that "in perpetuity" applies in any literal sense. This is so whether concerning curators charged with the overall care of museum objects, conservators responsible for their physical well-being, or directors intent on keeping existing donors placated and encouraging new potential benefactors. When asked how long "in perpetuity" might actually be, a prominent art museum director responded, "Thirty years."[13]

Similarly, though less cynically, conservators know that material stasis in an item subject to treatment is unattainable and that one of their roles is to minimize instability. Furthermore, conservators have largely abandoned talk of *reversibility of treatment*, that is, the notion that one can treat an item in such a way as to erase that treatment in the future, should it fail or be superseded or become otherwise undesirable. Instead, conservators have now adopted the norm of *retreatability* (or *removability*), according to which one treats a material thing so as to ensure its amenability to further treatment.[14] This is evidence of an increasing acceptance in contemporary conservation practice of material instability as chronically inevitable and an understanding that conservation can be no more than an attempt to manage change, not arrest it, let alone reverse it. Conservation scientists can do a great deal to analyze and account for the specific changes that materials undergo and can help conservators to formulate treatments that can decelerate or compensate for change. Some of their considerations are to be found in the "Materials" section of this volume.

Final Remarks

This concludes our mapping of the terrain of active matter, setting out what we take to be fundamental philosophical questions under two headings, conceptual and normative. Even as we ask what active matter might be, and under what conditions it is something to value or disvalue, we realize that we can do no more than indicate possible routes through the dark wood.

We should note that among the possible routes we have deliberately chosen not to take is the one usually discussed under the heading "agency."[15] Although humans, nonhuman animals, and other entities can affect one another in complex networks of action and reaction, the agency of humans differs from the agency sometimes ascribed to those others. It is only too easy to elide the distinctions among the various senses of agency, which is not a single predicate but a number identically termed. To do so can lead to the erroneous assumption that their respective properties are interchangeable. The changeability of changing matter and the activity of active matter may be affordances in psychologist James Gibson's sense, which ascribes complementarity of effect to constituents within an environment, but do not constitute agency of a kind analogous to the purposive agency of which humans are capable.[16]

The routes we have indicated, no less than the dark wood itself, may induce bewilderment in readers who expect this topic to be straightforwardly comprehensible. To dispel that bewilderment, the other philosophers who contribute to this volume—Sherri Irvin, Carolyn Korsmeyer, Alva Noë, and Yuriko Saito—in their own ways, and on their own terms, explore some of these routes further, as well as others as yet unmentioned. We are confident that clarification will follow. As Henry David Thoreau remarks in *Walden*: "All change is a miracle to contemplate, but it is a miracle which is taking place every instant."[17]

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Postscript: Philosophers at Work on Conserving Active Matter

The philosophy working group collaborated in a loose manner. This is largely owing to the nature of the discipline and the working habits of its practitioners. While we philosophers do gather to exchange ideas in society meetings, symposia, and workshops, we tend to do our writing alone.

Philosophers in our working group assembled at Bard Graduate Center on two occasions for symposia dedicated to the Conserving Active Matter project. The first was the initial discussion in November 2017, at which all four sections were represented. Philosophers Justin Broackes (Brown University), Sherri Irvin, and Carolyn Korsmeyer participated. The fourth of the sectional symposia, on philosophy, was held in November 2019. Sherri Irvin and Carolyn Korsmeyer participated once again, joined by philosophers Erich Hatala Matthes (Wellesley College), Alva Noë, Yuriko Saito, and Elisabeth Schellekens (University of Uppsala). Also taking part were conservator Francesca Esmay (Solomon R. Guggenheim Museum), architectural theorist Rumiko Handa (University of Nebraska), and independent curator and art historian Jeffrey Weiss. Thanks to the generosity of the Objects Conservation Laboratory of the Museum of Modern Art, conservator Roger Griffith, and curator Paola Antonelli, we were able to hold a workshop for the speakers in the laboratory the day before the 2019 symposium. This was the first time that most of the philosophers among the participants had ever been in a conservation laboratory. The discussion was very lively, indeed, and led to new appreciations of challenges faced by conservators, scientists, curators, and—for the first time—philosophers.

We have said that philosophers tend to write in isolation, but we (the authors) have collaborated on this project from the beginning. We produced what eventually became this introduction thanks to the support of the Lichtenberg-Kolleg (Advanced Study Institute in the Humanities and Social Sciences) of the Georg-August University, Göttingen, which gave us a shared office for an extended period as fellows in the spring of 2017. This allowed us to spend many hours together puzzling over conceptual definitions, covering whiteboards with endless arcane scribbles. We subsequently built on this foundation by sharing a document online that we could write and revise together simultaneously while discussing it by telephone once we were both back in the United States.

What is the contribution of philosophy to the topic of this volume? While philosophers have addressed related topics, such as the

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definition of art, for generations, we know of almost no philosophical discussion of conservation prior to this introduction and the chapters that immediately follow it. David Carrier's 1985 article, "Art and Its Preservation," is a rare exception.[18] A very few conservators have appealed to philosophy in their own writings. Salvador Muñoz Viñas is a recent exception who in his influential *Teoría contemporánea de la restauración*, published in 2003, mentions the work of several philosophers.[19] The only conservator we can cite who has attempted to engage with a conservation issue in a philosophical register, and did so creditably, is Steven W. Dykstra in his 1995 article, "The Artist's Intentions and the Intentional Fallacy in Fine Arts Conservation."[20] The consequence of this near absence of philosophical discussion of conservation is that we and our colleagues have had to address it from scratch in this project.

NOTES

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1. "Active Matter."
2. Tibbits, *Active Matter*, 11.
3. Das, Schmidt, and Murrell, "Introduction to Active Matter," 7185.
4. We are concerned with what scientists term *baryonic matter*: the product of baryons (composed primarily of protons and neutrons) that have not been annihilated by an encounter with antibaryons (antimatter particles). This is the ordinary matter of human experience. We acknowledge that not all philosophers subscribe to the definition of matter as that which is extended without qualification, for example, Bergson, *L'évolution créatrice*.
5. The taxonomic view proposes differences in *kind*; the spectral view proposes differences in *degree*.
6. We say "mostly distinct" so as to allow for the overlap of the different

subsets on the model of Ludwig Wittgenstein's *family resemblances*. Wittgenstein, *Philosophical Investigations*, part I, §§ 66–76, pp. 27–31.

7. Popa, *Between Necessity and Probability*. For debates in the philosophy of biology, see Weber, "Life."
8. Trifonov, "Definition of Life."
9. "MycoTEX Proof-of-Concept"; "Aguahoja."
10. Pure still water can be supercooled at standard atmospheric pressure to as low as about -40°C and stay liquid, prevented from solidifying by a lack of nucleation centers around which crystals form, afforded by tiny impurities or even vibrations. For recent research, see Kringle et al., "Reversible Structural Transformations." Our thanks to Daniel Lord Smail for drawing our attention to the supercooled state of water.
11. "Gold."
12. We address these questions in our contribution to the *Conserving Active Matter* website, 2022, https://exhibitions.bgc.bard.edu/cam/.
13. This was a jocular remark made to Ivan Gaskell in conversation; yet it reflects a complex English common-law doctrine, modified in various jurisdictions by statute, to inhibit *mortmain*: the prevention of the inclusion of provisions in a deed or a will that would continue to affect the ownership of property long after the person making those provisions is dead.
14. Muñoz Viñas, *Contemporary Theory of Conservation*, 183–89.
15. Discussion of agency is legion, relying directly or indirectly on the idea of *agencement* (usually poorly translated from French into English as "assemblage") in Deleuze and Guattari, *Milles plateaux*. Other influential exponents include Gell, *Art and Agency*, and Latour, *Reassembling the Social*. Elaborations of agency have come increasingly to resemble late medieval European attempts to retain the Ptolemaic account of the planets; see, for example, Bennett, *Vibrant Matter*. Notably, at the symposium "Conserving Active Matter" at Bard Graduate Center, New York (November 27–28, 2017), at which historians, Indigenous scholars, materials scientists, and philosophers spoke, the term "agency" was not used once in the nineteen papers delivered nor in discussion.
16. See, in particular, Gibson, *Ecological Approach*.
17. Thoreau, *Walden*, 11.
18. Carrier, "Art and Its Preservation."
19. Muñoz Viñas, *Contemporary Theory of Conservation*, passim.
20. Dykstra, "Artist's Intentions," 197–218.

BIBLIOGRAPHY

“Active Matter.” Hagan Group, Martin A. Fisher School of Physics, Brandeis University (website). Accessed August 4, 2021. https://www.brandeis.edu/physics/hagan/research/active-matter/index.html#:~:text=Active%20matter%20describes%20systems%20whose,components%20of%20the%20cellular%20cytoskeleton.

“Aguahoja.” Mediated Matter, MIT Media Lab. 2020. https://mediatedmattergroup.com/aguahoja.

Bennett, Jane. *Vibrant Matter: A Political Ecology of Things.* Durham, NC: Duke University Press, 2010.

Bergson, Henri-Louis. *L’évolution créatrice.* Paris: Alcan, 1907.

Carrier, David. “Art and Its Preservation.” *Journal of Aesthetics and Art Criticism* 43, no. 3 (1985): 291–300.

Dante Alighieri. *The Inferno of Dante Alighieri.* Rev. ed. Translated by John Aitken Carlyle. London: J. M. Dent, 1909.

Das, Moumita, Christoph F. Schmidt, and Michael Murrell. “Introduction to Active Matter.” *Soft Matter* 16 (2020): 7185–90.

Deleuze, Gilles, and Félix Guattari. *Milles plateaux.* Vol. 2 of *Capitalisme et schizophrénie.* Paris: Éditions de Minuit, 1980.

Dykstra, Steven W. “The Artist’s Intentions and the Intentional Fallacy in Fine Arts Conservation.” *Journal of the American Institute for Conservation* 35 (1996): 197–218.

Gell, Alfred. *Art and Agency: An Anthropological Theory.* Oxford: Clarendon Press, 1998.

Gibson, James J. *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin Harcourt, 1979.

“Gold.” Periodic table of the elements. Radio Chemistry Society (website). Accessed August 4, 2021. https://www.radiochemistry.org/periodictable/elements/79.html.

Kringle, Loni, Wyatt A. Thornley, Bruce D. Kay, and Greg A. Kimmel. “Reversible Structural Transformations in Supercooled Liquid Water from 135 to 245 K.” *Science* 369 (2020): 1490–92.

Latour, Bruno. *Reassembling the Social: An Introduction to Actor-Network-Theory.* Oxford: Oxford University Press, 2005.

Muñoz Viñas, Salvador. *Contemporary Theory of Conservation.* London: Routledge, 2011. First published as *Teoría contemporánea de la restauración.* Madrid: Editorial Síntesis, 2003. First English edition, Oxford: Elsevier Butterworth-Heinemann, 2005.

“MycoTEX Proof-of-Concept.” NEFFA: Growing the Future of Fashion (website). Accessed August 4, 2021. https://neffa.nl/portfolio/mycotex/.

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Popa, Radu. *Between Necessity and Probability: Searching for the Origin and Definition of Life*. Berlin: Springer, 2004.

Thoreau, Henry David. *Walden; or Life in the Woods* (1854). In *Walden and Other Writings of Henry David Thoreau*, edited by Brooke Atkinson, 3–312. New York: Modern Library, 1992.

Tibbits, Skylar, ed. *Active Matter*. Cambridge, MA: MIT Press, 2017.

Trifonov, Edward N. "Definition of Life: Navigation through Uncertainties." *Journal of Biomolecular Structure & Dynamics* 29, no. 4 (2012): 647–50.

Weber, Bruce. "Life." In *The Stanford Encyclopedia of Philosophy*. Summer 2018 ed. Edited by Edward N. Zalta. https://plato.stanford.edu/archives/sum2018/entries/life/.

Wittgenstein, Ludwig. *Philosophical Investigations.* 3rd ed. Edited by G. E. M. Anscombe and Rush Rhees. Translated by G. E. M. Anscombe. Malden, MA: Blackwell, 2001. First published in 1953.

Ivan Gaskell and A. W. Eaton, "Introduction: Active Matter—Some Initial Philosophical Considerations," in *Conserving Active Matter*, ed. Peter N. Miller and Soon Kai Poh (New York: Bard Graduate Center, 2022), 51–64.