Topoi (2023) 42:719–732
https://doi.org/10.1007/s11245-023-09885-7

The Radical Naturalism of Naturalistic Philosophy of Science

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Accepted: 10 January 2023 / Published online: 27 February 2023

Abstract
Naturalism in the philosophy of science has proceeded differently than the familiar forms of meta-philosophical naturalism in other sub-fields, taking its cues from "science as we know it" (Cartwright in The Dappled World, Oxford University Press, Oxford, 1999, p. 1) rather than from a philosophical conception of "the Scientific Image." Its primary focus is scientific practice, and its philosophical analyses are complementary and accountable to empirical studies of scientific work. I argue that naturalistic philosophy of science is nevertheless criterial for other versions of meta-philosophical naturalism; relying on a conflicting conception of scientific understanding would constitute a "first philosophy" imposed on the sciences. Moreover, naturalistic philosophy of science provides the basis for a "radically" naturalistic alternative to the familiar forms of orthodox or liberal naturalism. Goodman, Sellars and Hempel had previously challenged empiricist scruples against causal connections or nomological necessity by arguing that scientific concepts already had modal import. The radical naturalism I defend similarly challenges meta-philosophical naturalists' conception of the Scientific Image as anormative, and instead shows how the normativity of scientific understanding in practice is a scientifically intelligible natural phenomenon. This account then provides a basis for naturalistic reflection on how other practices and normative concerns fit together with the best scientific understanding of human ways of life.

Keywords Naturalism · Philosophy of science · Scientific practice · Radical naturalism · Normativity · Scientific Image · Scientific understanding

1 Naturalism in the Philosophy of Science

Anglophone philosophy's relation to the empirical sciences has undergone a widely recognized reorientation since around mid-20th Century. This turn toward a broadly naturalistic meta-philosophy has had double-edged implications. In one direction, Quine's (1969) rejection of "first philosophy" and Sellars's (2007, ch. 14) insistence on the philosophical primacy of the Scientific Image prominently abdicated philosophical authority over the natural sciences. The sciences ought not defer to empiricist scruples against explanatory appeals to unobservable entities, rational reconstructions of the sciences' conceptual or methodological developments, or other philosophically grounded constraints. Questions of how scientific inquiry should proceed and what can justify its conclusions are instead rightly posed and addressed from within the sciences. This deference to scientific autonomy has instead led philosophers to situate their own work within a broadly scientific conception of the (natural) world and also to rely on scientific developments to advance work in epistemology, metaphysics, philosophy of language and mind, and meta-ethics.

Widespread acceptance of the autonomy and philosophical centrality of scientific understanding has been accompanied by extensive disagreement over their implications. Advocates of a more stringent philosophical naturalism have insisted on the need to "place" the topics of philosophical inquiry within the world as scientifically understood or to account for them in methodological continuity with the sciences.[1] Proponents of some alternative approaches endorse naturalistic scruples against rational intuitions, supernatural entities, or transcendental arguments. They nevertheless argue that the consequences of these scruples are less restrictive. In particular, "liberal" naturalisms

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[1] Widely cited examples of ontological naturalism and the "placement problem" include Armstrong (1978) and Jackson (1998). Quine (1969) is a classic defense of methodological naturalism. Papineau (2021) carefully surveys and assesses various naturalist positionings.

encompass considerable autonomy from scientific determination for ethical, political, or aesthetic *normativity*, the *rationality* of thought, language, and epistemic justification, and the *existence* of diverse entities irreducible to the categories of the natural sciences (de Caro and Macarthur 2004, 2010, 2022). Even resolute critics of both sets of views have gone along partway with the naturalistic turn in philosophy. Contemporary philosophical "anti-naturalists" now mostly accept scientific authority over the natural world and only seek to legitimate a transcendence of nature in particular domains—ethical norms, rational intuitions, religious faith, or qualitative consciousness.

One initially surprising consequence of these developments has been the isolation of philosophy of science from the rest of the discipline. In the middle decades of the past century, philosophers of science—Carnap, Sellars, Popper, Quine, Hempel, Putnam, Goodman, Feyerabend, or Toulmin—figured prominently in debates in other philosophical sub-fields. The standards of scientific confirmation, explanation, or concept formation were understood to exemplify norms of human rationality more generally. As philosophers of science instead began to situate their inquiries amidst conceptual or methodological debates within particular scientific domains, their work became increasingly inaccessible and seemingly irrelevant to philosophical work on other topics. A consequence from one direction has been that philosophers of science now usually focus specialized attention on particular sciences, with less concern to address other developments in philosophy. The consequences have been more significant in the other direction, however. Interpretations of particular scientific findings by philosophers of science have been recognized in some other areas of philosophy, but not their evolving accounts of scientific practice and understanding. A central thesis of this paper is that meta-philosophical debates over naturalism have lost their grounding in the best available accounts of scientific understanding, in ways that undermine their self-conception as naturalists.

Philosophy of science has undergone its own naturalistic turn, mediated by initial resistance to and eventual accommodation with empirical studies in the history, sociology, psychology, anthropology, and feminist studies of scientific work, and often led by philosophers attentive to work in the so-called "special sciences."[2] Serious, sustained philosophical studies of scientific understanding and how it is achieved instead increasingly recognize the historical vicissitudes, institutional embeddedness, material realization, normative complexity, disciplinary diversity, and political engagement of scientific understanding in practice.[3] These empirically discernible features of scientific inquiry are no longer regarded as deficiencies or limitations in contrast to philosophical ideals of scientific understanding. They are instead recognized as integral to how scientific work painstakingly develops and extends conceptual grasp of the world we inhabit.

The disciplinary autonomy and even isolation of philosophy of science from other philosophical sub-fields has mostly prevented serious attention to how naturalism in the philosophy of science is related to any more encompassing meta-philosophical naturalism. Philosophers of science typically make three main points in describing their approach as naturalistic. First and foremost, they aim to analyze what Nancy Cartwright succinctly summarized as "science as we know it: apportioned into disciplines, apparently arbitrarily grown up; governing different sets of properties at different levels of abstraction; pockets of great precision; large parcels of qualitative maxims resisting precise formulation; here and there, once in a while, corners that line up, but mostly ragged edges; and always the cover of law just loosely attached to the jumbled world of material things" (1999, 1). There is no better science than the science we have as an ongoing, historically developing research enterprise.

A second consideration is that the primary target of philosophical understanding is now scientific *practice*. Julia Bursten's summary of how philosophers of science now understand scientific classifications of kinds exemplifies this shift:

> [W]hether or not kinds are natural, whether or not they have essences, and whether or not the extensions of kind terms change on Pluto or Twin Earth, kinds are tools that scientists use to carry out the practices of science. From the problem of species classification in biology to the development of the standard model in particle physics, kinds are useful to science insofar as they can help scientists to determine how to carry out an experiment, confirm a theory, or explain a set of natural phenomena. (2016, 5)

These first two considerations then lead to the third: the concern to account for scientific practice as we know it answers to a range of empirical approaches. Philosophers of science often do employ a characteristically philosophical toolkit to address issues of conceptual content, ontological

[2] Prominent historical markers for this shift include Ronald Giere's (1985) proposal for a naturalized philosophy of science, Arthur Fine's (1986a ch. 7–8, 1986b, 1991, 1996) papers on the Natural Ontological Attitude, Werner Callebaut's (1993) wide-ranging interviews of naturalistic philosophers of science, prominent edited volumes (Pickering 1992, Galison and Stump 1996) bringing together philosophers, historians, sociologists, and feminist scholars in constructive conversation, the subsequent mutually productive engagement of philosophers, historians, and sociologists in the International Society for the History, Philosophy, and Social Studies of Biology (https://www.ishpssb.org/), and the founding of the Society for the Philosophy of Science in Practice (https://www.philosophy-science-practice.org/).

[3] Salient examples include Ankeny and Leonelli (2016); Barad (2007); Bechtel (2006); Cartwright (2019); Douglas (2009); Dupre (2012); Giere (2006); Hacking (2009); Kitcher (2001); Mitchell (2009); Nersessian 2008; Rouse 2015, Part II ; Solomon 2015; Winsberg 2018; Wylie (2002).

import, or the norms and forms of reasoning, explanation, or data analysis. These philosophical concerns are nevertheless understood as both complementary and accountable to a diverse range of other empirically discernible aspects of scientific work.

In the remainder of the paper, I argue that conjoining these two distinct philosophical turns toward naturalism leads to a more radical meta-philosophical naturalism in place of the familiar orthodox and liberal alternatives. This more radical naturalism is a straightforward extension of how developments in the philosophy of science contributed to the earlier naturalistic turn in philosophy that took root at mid-20th Century. The previously dominant forms of empiricism had mostly endorsed Hume's skeptical concerns about the empirical accountability of causal or alethic modalities. Observers could supposedly discern the spatiotemporal contiguity of events but not their causal connection. Empirical evidence could show what regularly does happen, but not what *would* happen counterfactually or subjunctively. Taken together, Goodman (1954), Sellars (1957, 1997), and Hempel (1965) showed instead that empiricists had misconstrued scientific conceptualization in their supposed contrast of scientific facts to the modal characterization of causes or laws. The sciences do not describe the world in non-modal terms. The counterfactual and subjunctive projectibility of scientific concepts is indispensable to conceptual content, experimental design, empirical confirmation, and scientific explanation. Empiricists had wrongly presumed that modal determinations would have to be *added* to conceptually articulated but non-modal facts, and would thus require more extensive justification than any evidence could provide. Counterfactual and subjunctive invariance was instead already integral to and pervasive in scientific understanding, and those empiricist scruples were recognizable as an unjustified philosophical imposition on the sciences.

Naturalistic philosophy of science similarly challenges familiar meta-philosophical appeals to a scientific conception of the world as *anormative*. Prominent among the domains subject to ontological naturalists' "placement" problems are normative claims about what one ought to say or do. Some orthodox naturalists discard moral and other normative claims as not truth-apt. Others attempt to salvage normative statements via fictionalist, quasi-realist, expressivist, and other non-cognitivist accounts of their normativity. Liberal naturalists divide an anormative domain of scientific intelligibility from a more encompassing conception of nature or of human life as second-natural. Underlying all these efforts has been the assumption that the sciences provide a conception of the natural world as anormative facts, much as empiricists had previously imagined a scientific image of non-modal facts. Both assumptions are chimeric. Scientific understanding of the world not only extends counterfactually and subjunctively. Scientific understanding is irreducibly normative in its methodology, conceptualization, practical performances, and assessments. Moreover, recent work in philosophy of science shows that the alethic-modal and normative aspects of scientific understanding work hand in hand (Lange 2000, 2007; Haugeland 1998, 2013; Rouse 2015 ch. 8–10).

Both empiricist conceptions of scientific intelligibility as amodal and meta-philosophical naturalists' conceptions of it as anormative are rooted in not taking scientific conceptualization sufficiently seriously. Empiricists did not adequately recognize the role of modally robust conceptualization in empirical confirmation, explanatory significance, and methodological guidance. Contemporary meta-philosophical naturalists have also misconceived scientific conceptualization as mental representations that have no effect on the world represented. They fail to recognize the role of normatively robust scientific practices in enabling the scientific intelligibility of the world. The role of experimental systems (Hacking 1983; Rheinberger 1997; Cartwright 1999; Ankeny and Leonelli 2016), causal intervention (Cartwright 2007; Woodward 2021), data analysis (Galison 1996; Leonelli 2016), modeling (Giere 1999; Wilson 2006; Weisberg 2013) and epistemic risk (Biddle 2016; Elliott and Richards 2017) as integral to scientific conceptualization and understanding are not just aspects of how people think, but also of how the natural world is intelligible conceptually.

Recognizing the ineliminable, empirically accountable normativity of scientific understanding not only undercuts orthodox naturalists' efforts to reduce, eliminate, or place normative determinations in relation to supposedly anormative but modalized determinations of scientific facts. The autonomy that liberal naturalists ascribe to other normative domains also depends on their presumptive contrast to scientific understanding of the natural world as anormative. A more radical naturalism instead shows the mutual accountability between the normativity of scientific understanding of the natural world and recognition of that scientific understanding as a scientifically intelligible natural phenomenon (Rouse 2015). This conception of the scientific intelligibility of the normativity of scientific understanding in practice then provides a renewed basis for naturalistic reflection on how other practices and normative concerns fit together with the best scientific understanding of human ways of life (Rouse 2023).

I develop this line of argument in three stages, beginning with how naturalistic philosophy of science challenges orthodox and liberal conceptions of meta-philosophical naturalism. I then consider the constructive implications of naturalized philosophy of science for a more radical meta-philosophical naturalism that could encompass scientific practices as scientifically intelligible natural phenomena. The concluding section takes up how naturalized philosophy of science is situated within this more encompassing meta-philosophical naturalism.

2 The Naturalistic Challenge to Extant Meta-philosophical Naturalisms

The more orthodox forms of naturalism characterize in varied ways the philosophical sufficiency or completeness they each ascribe to scientific understanding. The distinction between ontological naturalism—the entities playing a role in scientific explanations are the only entities there are—and methodological or epistemological naturalism—scientific inquiry and its methods provide the only genuine or reliable basis for knowledge—is one familiar dividing line. Orthodox naturalists also split over the unity of science. Physicalists insist that what there is is ultimately reducible to or supervenient on physical entities, or that the "special sciences" are dependent on or legitimated by an understanding of their physical basis; pluralists recognize the ontological and/or methodological autonomy of astronomy, chemistry, biology, the neurosciences, psychology, and geology or the environmental sciences. Differences also arise concerning which explanatory constituents or strategies are taken over from their favored sciences: do the sciences uncover singular causes, causal structure, counterfactually robust regularities, governing laws or symmetries, or some combination thereof, or do naturalists simply defer to scientific authority by accepting whatever explanatory strategies the sciences invoke?

All of these views deploy a dual conception of "the scientific image," encompassing both an image of nature as conceived and explained scientifically, and an image of what a genuinely scientific understanding of nature would be. Ontological naturalists are committed to some version of what Teller (2001) tellingly and critically depicts as "the Perfect Model Model" of scientific understanding. Methodological naturalists presume some way of demarcating genuine scientific methods or achievements, and perhaps of specifying scientific "methods" in ways that can be distinguished from their entanglement with theoretical understanding of their domains, the practical skills of experimenters, and the capacities and limits of instruments, materials, and experimental systems. Orthodox naturalists also respond variously to recognition of the fallibility and incompleteness of current scientific understanding and methodological choices. Whether a naturalistic conception of what there is or of how it can legitimately or reliably be known appeals to the ontological commitments or methodological choices of a presumably more adequate future science, or insists that philosophy can do no better than to work within the limits of the best contemporary science, orthodox naturalism must accommodate ongoing revision of the dual scientific image.

Recognition of this two-sided character to meta-philosophical naturalists' understanding of the "scientific image" shows why naturalism in the philosophy of science takes priority over any meta-philosophical naturalism. The adequacy of the latter views' conceptions of a scientific image of nature depends on the adequacy of their implicit conception of scientific understanding. Otherwise, these meta-philosophical naturalisms would violate their own commitments by imposing their own "first philosophy" on the sciences. In what follows, I argue that naturalistic philosophies of science show how both orthodox and liberal naturalisms impose on their conceptions of the sciences what I have elsewhere characterized as an epistemologically-based first philosophy (Rouse 1996, 2005, 2015 ch. 5–6). The challenge to familiar meta-philosophical naturalisms does not concern their intramural disputes over whether the sciences provide a conceptually unified or comprehensive image of the (structure of the) natural world or instead provide a partial and multi-leveled conceptual patchwork at multiple scales, ontological levels, or disciplinary orientations. The question is instead whether the sciences aim for or produce a consistent representation of the natural world at all, in at least two respects.

The first respect arises from the research orientation of scientific practice, which challenges orthodox and liberal naturalists alike. They typically identify a scientific conception of the world with a body of justified or reliable scientific knowledge. Scientific researchers, however, understand their domains in ways that exceed and revise what can be codified as established knowledge, and are oriented toward its further conceptual refinement, extension, and revision. The scientific review literature does not compile a comprehensive summary of what is already known, but instead reorganizes past achievements as relevant background that orients subsequent research toward revision of the sense and significance of current conceptual and experimental capabilities. The revisionist orientation of current scientific understanding is neither a determinate specification of doubts nor merely an empty recognition that some revisions will be required somewhere. As historian of biology Hans-Jörg Rheinberger indicates, the "epistemic objects" towards which scientific understanding is directed in research

> are material entities or processes—physical structures, chemical reactions, biological functions—that constitute the objects of inquiry. As epistemic objects, they present themselves in a characteristic, irreducible vagueness. This vagueness is inevitable because, paradoxically, epistemic things embody what one does not know. (1997, 28).

That orientation is vague rather than empty because the technical skills, experimental systems, theoretical models, and projected interventions in research give scientists' understanding a more or less definite direction. That vagueness is irreducible, because as objects of inquiry acquire greater determinacy, they are reconfigured and reoriented as components of a research practice directed ahead toward new targets of inquiry. The horizon of scientific understanding in the live practice of research always recedes.

Scientists do sometimes contribute to summarizing an epistemic consensus, as in the reports of the Intergovernmental Panel on Climate Change or medical consensus conferences. When they do so, however, researchers' own understanding of the field is usually already directed beyond what can be assimilated within an acceptable consensus. The difference is readily expressible in Sellarsian terms. Orthodox and liberal naturalists both identify "the scientific image" as a position within the space of reasons, a body of claims that have been justified and accepted scientifically, or as Huw Price put it, "the sum of all we take to be the case" (2011, 28). Scientific understanding in practice instead reconfigures whole segments of the space of reasons. It encompasses a collective grasp of what could be intelligible and significant projects, defensible positions, reasons for or against those positions, and possibilities for extending or revising them. The sciences offer not a single synchronic "image" of the world, but a temporally extended field of research opportunities, intelligible disagreements, outstanding problems, and the conceptual and practical capabilities that guide them (Rouse 2015, ch. 6). Scientific understanding reaches out from, beyond, and partially against "what we take to be the case."

The second respect in which naturalistic philosophy of science challenges familiar notions of a "scientific image" concerns the synchronic use of diverse and often mutually contradictory models of the same entities, processes, or interactions. As Wilson (2006) has argued, not only are scientific concepts modeled or applied in divergent ways in different parts of the same domain, in "patches" or "facades" that admit of no unified treatment. The same phenomena are also sometimes modeled in contradictory ways for different purposes. In discussing models of forces and motions in classical mechanics as an exemplary case, Wilson notes that,

> [o]ne is usually provided with accounts that work approximately well in a limited range of cases, coupled with a footnotes of the 'for more details, see ...' type.... [These] specialist texts do not simply 'add more details' to Newton, but commonly overturn the underpinnings of the older treatments altogether. (Wilson 2006, 180–181).

If one argues that all but one member of these sequences are approximations to the most detailed and precise models, one must confront the difficulty that some models of theoretically central concepts admit of no more-principled models. Andrea Woody points out that such conceptually central models as for an ideal gas, the groupings on the periodic table, or the molecular orbitals that model the geometrical shape of molecules that share electrons in covalent or ionic bonds have no more principled representation. There is no *general* mathematical representation of gas behavior more precise than the van der Waals law. Woody also likens the effort to discern principled quantum mechanical determinations of chemical groupings like 'halides' or 'transition metals' or the molecular orbitals that are useful for predicting reaction propensities as "*post hoc*—something akin to seeing objects in the patterns of clouds" (2004, 28).

Philosophers of science increasingly recognize that what is at issue in how scientists model the phenomena they study is not what these models *say* about the world—their contribution to an overall scientific image—but instead what scientists and others can *do* with those models, including what they can do conceptually. The point is clearly illustrated by how scientists model chemical substances and their interactions at multiple scales. Bursten (2016) shows in passing how the compositional assumptions of ontological naturalists are undermined by the classificatory concerns of the sciences. In the classical philosophical example of gold, Bursten argues that

> [t]he identity-determining features of chemical and nanoscientific kinds align with different length scales of interest to different projects within those sciences.... [I]n a synthetic setting, [t]he macroscopic lump of gold has macroscopic properties—ductility and malleability, as well as chemical inertness—that are similar to other noble metals (such as palladium or platinum) as well as many plastics. The gold atoms, on the other hand, have electronic symmetry, namely $d^{10}s^1$, that is shared by copper and silver. ... [S]cale has dictated a difference in the kinds of kinds that are relevant in each setting. As for the gold nanoparticles, [that] their surface chemistry, shape, and size are ... the features ... that generate relevant alternatives still illustrates the point that classification in the sciences depends on scale and scientific intent. (2016, 20–21).

Winsberg (2010, ch. 5) similarly considers an example in which properties of the same material are not only modeled in mutually contradictory ways at different scales: as a continuous macroscopic substance, as groups of molecules interacting with classical dynamics at nanoscales, or as quantum mechanical models of chemical bonding where the material fractures. What happens at these different scales has mutual effects that then require "handshaking models" to mediate between these conceptually inconsistent models. For handshaking purposes, the differences between the hydrogen and silicon atoms that compose the surface are ignored to consider average behavior modeled as fictitious "silogen" atoms. What matters is not how to describe the world scientifically, but how to understand and engage with it effectively for various purposes. That practical orientation is not an instrumentalist representation, but a conceptual pluralism that discerns, brings about, and responds to many "real patterns" in the world (Dennett 1991).

Methodological naturalisms fare no better within a naturalized philosophy of science. Philosophers of science usually do not talk of scientific methods generally, but instead of the variety of methods deployed in particular disciplines or research programs. These considerations often involve the construction and utilization of particular experimental systems, including model organisms, and the variety of skills, procedures, instruments, and preparations those systems require. Often the methods invoked in such practices develop in close dialectic with the conceptual and theoretical understanding of the phenomena studied and the instruments deployed. The methods used to investigate a domain continue to evolve with how scientists conceive the domain. Similar points could be made about critical assessment of the mathematical objects and operations used in scientific inquiry, which is normally undertaken within the domains and for the purposes for which such objects and operations are being deployed. Often the methodological considerations involved in scientific understanding are tailored to human cognitive capacities and the accuracy and precision of the instruments and procedures employed. Arguably, the "methods of science" that naturalists invoke as criterial for scientific understanding and philosophical work offer no more general guidance than to use "the right tools for the job" (Clarke and Fujimura 1992). In any case, recognition of this far-reaching methodological pluralism reminds us that this version of naturalism does not specify to *which* scientific disciplines or which methods philosophical understanding should defer.

Taken at first glance, these aspects of "science as we know it" might then seem to support some more liberal version of naturalism. For example, Price (2011, ch. 9) proposed that what matters most for philosophy is not an ontological, epistemological, or methodological "object naturalism," but a "subject naturalism" that accounts for human beings and our capacities and ways of life as natural phenomena. Price argues that traditional forms of object naturalism require validation from a subject naturalist perspective, and that such validation might not be forthcoming. Moreover, he rightly suggests that the priority he ascribes to subject naturalism is only a

> threat to a particular philosophical conception of science, rather than to the scientific enterprise itself. If we equate science with the perspective-free standpoint, the view from nowhere, then science so conceived is certainly under threat. But why not see this simply as a challenge from within science to a particular philosophical conception of science? (2011, 31).

Price and other liberal naturalists may thus recoil from some familiar conceptions of the scientific image, but they also match the orthodox in their inattentiveness to the more complex portrayals of scientific practice and understanding in recent philosophy of science and interdisciplinary science studies.

A second look then suggests that Price's version of naturalism, or those of Davidson, Putnam, McDowell, Brandom, and others assembled under the banner of "liberal naturalism," do not yet sufficiently accommodate what is to be learned from naturalism in the philosophy of science. Apart from sometimes endorsing a more pluralistic conception of the sciences, liberal naturalists typically rely on accounts of scientific understanding consonant with those endorsed by more orthodox naturalists. For McDowell (1994), natural scientific understanding is the realm of law; for Brandom (1994, 2000), it is a non-normative causal order; Davidson (1980) argues more specifically for a closed, "homonomic" causal system; Price refers to "the sum of all we take to be the case" (2011, 28). These characterizations of scientifically intelligible nature as anormative parallel earlier empiricist presumptions that science can describe the world amodally.

Those traditional philosophical conceptions of a "scientific image" do important work in liberal naturalist accounts, serving as foils to their conceptions of nature and naturalism as more inclusive than the scientific image of the natural world; they presume that normative considerations must be *added* to a natural world that is intelligible as anormative. Thus, for example, McDowell (1994) contrasts acculturated second nature to law-governed first nature; Davidson's (1980) anomalous monism allows only token identity between events classified within a closed system of laws and those same events interpreted under the constitutive ideal of rationality; Price (2011) emphasizes the autonomy of other linguistic practices from natural scientific determinations of what is the case; Macarthur (2010) calls for an expansive naturalism that "takes the human sciences seriously." In one way or another, each introduces a conceptual separation between an anormative scientific domain of laws or causes and the human practices that enable rational responsiveness to norms. Scientifically intelligible nature is supposedly impervious to rational normativity, while the normative concerns instituted by human practices operate within scientifically intelligible nature but with a normative authority constituted on other grounds.

Naturalized philosophy of science instead shows that distinctions between causal or nomological facts and the rational normativity of other practices or language games marks a false contrast. On one hand, scientific practices and scientific understanding are among those normative engagements within the natural world. The sciences do not produce a single coherent description of the world or its causal or nomological structure, but alternative classifications and characterizations appropriate for different purposes (Wilson 2006; Lange 2000; Bursten 2016). Different sciences have different explanatory interests and research orientations which guide how they conceptualize their domains and which of those conceptualizations is scientifically significant (Lange 2000; Woody 2004; Kitcher 2001, ch. 6). Those conceptualizations are also tailored to human cognitive capacities and their mathematical and computational extensions (Teller 2001; Woody 2004; Warwick 2003; Woodward 2021). The empirical accountability of those conceptualizations depends on the lawful counterfactual invariance that makes their confirmation projectible to previously unexamined cases (Goodman 1953, Lange 2000). That lawful invariance is nevertheless also sustained by its reflective equilibrium with normative concerns of proper performance of experimental tests, discernment of relevant signals from background noise, the relevant and attainable degrees of empirical precision, and constitutive distinctions between *ceteris paribus* exceptions and disconfirming cases (Haugeland 1998, ch. 13; Lange 2002; Cartwright 1999, 1989; Rouse 2015, ch. 8; Hacking 1992, 2009).

These normative concerns that guide scientific understanding in practice are also not autonomous. Scientific investigation materially as well as conceptually transforms the world, introducing new phenomena, making consequential choices among alternative material re-arrangements, and introducing opportunity costs (Hacking 1983; Rouse 1987; Barad 2007). The resulting epistemic risks and the diverse normative concerns relevant to their assessment bear on the constitutive normativity of scientific understanding (Biddle and Kukla 2017). That mutual accountability to other normative concerns also extends to the sciences' interested explanatory orientations and consequential judgments of scientific significance (Lange 2000, 2007; Kitcher 2001), and the ethically fraught interventions they sometimes undertake (e.g., Cartwright 2019, Reardon 2005, Tallbear 2013). Normative aspects of scientific confirmation, explanation, and conceptualization are thereby entangled with responsibility to justice and other normative concerns (Kukla 2008; Reardon et al. 2015).

Recognition of the constitutive normativity of scientific intelligibility dissolves orthodox naturalists' concern to "place" normative phenomena with respect to an anormative nature. Liberal naturalists nevertheless draw an unjustified inference from their contrasts between a scientific image of nature and their more inclusive versions of naturalism. They implicitly presume that if "core normative phenomena such as reasons and values" need not be "placed" within the scientific image or discerned in accordance with scientific methodologies, then these normative concerns are thereby freed from accountability to natural scientific understanding apart from blocking appeals to "supernatural" authority (de Caro and Macarthur 2010, 3, 9). The question instead remains open whether a naturalized philosophy of science offers a different basis for understanding ourselves as natural beings and our accountability to diverse normative concerns as natural phenomena. The dualism of the natural and the normative embedded in the familiar approaches to naturalism blocks adequate consideration of relations in both directions between scientific understanding in practice and other practices and their constitutive normative concerns. The naturalistic re-conception of scientific understanding might nevertheless also provide a more general basis for thinking about various forms of normative accountability as natural phenomena informed by scientific understanding.

3 Meta-philosophical Implications of Naturalistic Philosophy of Science

If scientific understanding is embedded in scientific research practices rather than as a free-standing system or collection of facts or laws that those practices certify, then considering relations between scientific facts and other kinds of fact is the wrong way to think about the philosophical primacy that naturalists accord to scientific understanding. Some liberal naturalists do point toward a constructive alternative, however. De Caro and Macarthur point out that liberal naturalists avoid "countenancing the supernatural, whether in the form of entities (such as God, entelechies, or Cartesian minds), events (such as miracles or magic), or epistemic faculties (such as mystical insight or spiritual intuition) … [by opposing] the view that normative facts hold wholly independently of human practices" (2010, 3). Grounding the authority of normative concerns in world-involving human practices is central to naturalistic philosophy of science, which insists that the normativity of scientific understanding answers to scientific practices rather than to reasoning about those practices on autonomously philosophical grounds. The broader meta-philosophical issue then concerns the relationship between scientific understanding in practice and the normative concerns that animate and guide other aspects of human ways of life. Naturalized philosophy of science provides the basis for a meta-philosophical naturalism that takes the historical emergence of scientific practices as the basis for more adequate understanding of all other aspects of human life.

This approach would be a *radical* naturalism, in contrast to familiar orthodox and liberal versions of naturalism (Rouse 2022). It is "radical" in the sense that it begins at home, in a naturalistic account of scientific practices and scientific understanding. That account then provides the basis for a more encompassing naturalistic understanding of human ways of life as scientifically intelligible. Grasping how scientific practice and scientific understanding are scientifically intelligible natural phenomena has two mutually reinforcing components. This section takes up the first component, the specific version of what Price (2011) called "subject naturalism" worked out in the first part of *Articulating the World* (Rouse 2015). Drawing extensively on recent developments within evolutionary biology and the cognitive sciences, it laid out a conception of language and other human conceptual capacities as the outcome of an extended, iterated process of niche constructive biological evolution. The other component of the account, discussed in the second part of that book, showed how to understand scientific practices as both *exemplifying* that evolutionary account of human conceptual capacities and also *encompassing* that account within the scientific practices we have. The mutual support between these two components is critical to vindicating their naturalistic credentials. The conceptual capacities exercised in scientific work and many other aspects of human life must be adequately situated within the best scientific understanding of the world and our place within it. This explicative and explanatory project must in turn be shown to exemplify an empirically responsible account of scientific work as we know it.

Recognizing scientific understanding as a scientifically intelligible natural phenomenon points toward an alternative approach to a meta-philosophical naturalism. Naturalists have traditionally aimed either to show how to accommodate some normative concerns within nature understood as anormative, or else to eliminate them as incompatible with naturalism. Radical naturalism instead recognizes biological normativity as itself a scientifically intelligible natural phenomenon. It aims to account for the normativity of scientific practices and the many other practices that make up human ways of life as more complex, evolved forms of biological normativity. This strategy may seem superficially familiar, as some orthodox naturalists have already looked to evolutionary biology as an anormative basis for scientific explanation of many aspects of human life. Those accounts treat evolutionary fitness—a propensity to produce offspring in subsequent generations—as the underlying basis for what would then only *seem* to be complex forms of purposiveness and normative accountability.[4] Philosophers, biologists, and social theorists have rightly argued that such approaches have consistently failed to account for the normative complexity of human ways of life.[5] More fundamentally, however, the notion that evolutionary biology vindicates a conception of the natural world as anormative is a widespread but serious misunderstanding of the science.[6]

The idea behind these misconceptions of evolution is that biologists supposedly account for apparent forms of organismic purposiveness or normativity in terms of the *de facto* differential survival of organisms and lineages and the causal-functional contributions of their traits and behaviors to that outcome. Susan Mills and John Beatty (1979) point out, however, that the relevant concept of adaptive fitness is not the *actual* reproductive success of individuals, populations, or phenotypic traits. Success might result from factors other than fitness, and equating fitness with success would also trivialize its explanatory power. Fitness is instead a *propensity* to produce offspring which is normally assessed with *optimization* models (Maynard Smith 1978). Key assumptions in these models are the range of phenotypic variation, the aim or goal to maximize, the population structure, and its mode of inheritance (Maynard Smith 1978, 52). The aim or goal to maximize is not itself a causal-functional role, but the continuation of the life of an organism and its reproduction in subsequent generations. Models often address a component of fitness, such as rates of energy intake while foraging, which might itself be understood functionally (Maynard Smith 1978, 52). The modeled component of fitness is nevertheless functional only to the extent that it contributes to the successful maintenance and reproduction of the lives of organisms and their descendants, including how those traits develop and evolve. Whether it does so contribute, however, depends on how it interacts holistically with other interdependent "components" of fitness, including those that fall outside the models.

Radical naturalism proceeds differently by showing how the human lineage has evolved more complex forms of biological normativity, which include the conceptual accountability of scientific understanding. Human beings are evolved and developing organisms in an evolving lineage. Organisms are not self-contained entities, but instead ongoing processes sustained by exchange of energy, other resources, and waste products with their environments. When that process ceases, the organism is no more; when it leaves no descendant processes, the lineage is extinct. An organismic lineage's environment is not its physically

[4] Classic examples of this approach include Wilson (1975), Cosmides, Tooby, and Barkow (1992), and Buss (2008).

[5] Important examples of such criticism include Cowie (1999), Sterelny (2003) Part III, Buller (2005), Lloyd (2008) ch. 9, Laland and Brown (2011).

[6] I am grateful to an anonymous referee for *Topoi* who called attention to the need to address conceptions of evolutionary biology as vindicating a conception of nature as anormative.

specifiable surroundings, but rather "a spatial and temporal juxtaposition of bits and pieces of the world that produces a surrounding for the organism that is relevant to it, … [a] space defined by the activities of the organism itself" (Lewontin 2000, 52–53). The converse is also true: the organism's traits and way of life are ways of responding to and acting on its environment. These developmental and evolutionary processes are causally bidirectional, because organisms change their environments and thereby affect the selection pressures on their lineages. The behavior of conspecifics and other organisms is often a central component of a lineage's developmental and selective environments. The process of niche construction thus extends beyond physical reconstruction of environments and migration to new ones, to encompass behaviors that contribute to the developmental reconstruction and evolutionary maintenance of those behavioral patterns and their descendants in subsequent generations.

Organismic development and evolution are normative as Aristotelian *energeia*, goal-directed processes whose goal is the continuation of that very process in whatever form it subsequently takes (Okrent 2007, 2017). They succeed or fail in sustaining that process through multiple generations, but for most organisms that success or failure is all that is at stake biologically. The basis for a more complex normative accountability emerged with the development of a socially cooperative way of life in the hominin lineage in place of the socially coordinated activities common to other primates (Sterelny 2012; Tomasello 2008, 2014, 2019; Laland 2017; Rouse 2015, 2023). Cooperative participation in shared projects enables the differentiation of multiple interdependent practices, through which people could undertake activities dependent on supportive performances and practices carried out by others. People thereby develop different skills and live different lives, enabled by others' closely coupled skills, performances, and practices. Sustaining such coupling in changing circumstances requires effort, because these coupled, situated performances and practices can become partially decoupled. That happens because people work together in ongoing practices which they nevertheless understand in divergent ways; they differ in their commitments to a practice, their roles within it, and the extent of their relevant experience and expertise; each must accommodate their own involvement in a practice with many other practices in which they participate; other practices change in ways that withdraw supportive alignment or conflict with a practice; and circumstances change. In the face of a partial decoupling or misalignment among performances and circumstances, people need to act in ways that would restore their coupled interdependence or provide a new basis for their own performances and practices. Doing so is nevertheless a consequential achievement that must be continually maintained and reproduced. Maintaining such cooperative interdependence is thus challenging even for people with evolved and developmentally nurtured dispositions to cooperate. It requires ongoing adjustments, interventions, repairs, admonitions, refusals, sanctions, and other ways of bringing decoupled performances and circumstances back into accord.

The evolution of a practice-differentiated way of life thereby constitutes a more complex, two-dimensional biological normativity. Like organisms and lineages, the coupled performances that make up a practice or an interdependent nexus of practices only continue by reproducing themselves over time. Practices thereby have their own internal goal-directedness, marked by their characteristic skills, virtues, successes, and other achievements that motivate and sustain participation. They are nevertheless also open to assessment for their contribution to the success or failure of the organismic lineage to which they belong. That might initially seem to conjoin a biological normativity of maintaining life and reproducing the lineage with "socially" differentiated normative concerns that animate particular practices. The constitutive goal-directedness of a practice-differentiated way of life is then no longer limited to survival of the lineage, however. Practices depend on one another in ways that open a further range of normative concerns for *how* various practices fit together within individual lives and their encompassing, practice-differentiated way of life. Normative concerns for how that way of life would (or ought to) continue take their place within a more complex field of goal-directedness and assessment. Familiar examples of such integrative concerns include social justice, participatory governance, life balance among competing demands, collective power or achievement, individual freedom, personal ties of kinship and affiliation, environmental sustainability, or religious commitment. People do not just act for the sake of normative concerns internal to the particular practices they take up or to maintain life and lineage. They are also responsive to issues raised by how the practices that make up their lives and way of life depend on, support, and answer to one another.

Communicative and expressive practices—language, imagery, music, ritual, ostensive and expressive gesture, dance and theater, and so many more—emerged amidst a cooperative, practice-differentiated way of life. These practices and their performances had their own characteristic two-dimensional normative accountability. In one dimension, they must "make sense" to other participants and answer to their own constitutive forms of satisfaction and excellence. They nevertheless also contribute to the acquisition, coordination, and expression of the skills and concerns constitutive of other practices. Recent work on the evolution of language and other expressive practices has emphasized the importance of active teaching of others, above and beyond merely attentive social learning, in enabling the continuation and improvement of skills, roles, equipment, and procedures (Sterelny 2012; Tomasello 2008, 2014; Laland 2017; Tomlinson 2015, 2018). That role contributes to the niche constructive feedback loop that has been widely proposed as creating and reinforcing selection pressures for the enhancement and genetic assimilation of linguistic complexity, skill, and acquisition (Dor and Jablonka 2000; Bickerton 2009, 2014; Dor 2016). The salience of language and other communicative and expressive practices in the developmental environments of human infants led to the gradual genetic assimilation of people's capacities to grow into language and thereby provide the requisite developmental environments for subsequent generations.

This approach to understanding human social life and cognitive capacities as an evolved biological phenomenon is importantly different from earlier attempts to "naturalize" the normative complexity and diversity of human ways of life in evolutionary terms. It neither aims to reduce that normative complexity to the one-dimensional normativity of enhanced inclusive fitness nor postulates a separate modality of cultural evolution distinct from but enabled by biological evolution understood more narrowly as genetic transformation.[7] A practice-differentiated way of life and its two-dimensional normativity evolved in the hominin lineage through the same conjoined processes of natural selection and niche construction that occur in all lineages. That continuity importantly differentiates the resulting radical naturalism from the liberal approaches whose meta-philosophical naturalisms aim to vindicate a relative autonomy of many aspects of human life from accountability to natural scientific understanding. A radical naturalism instead shows how both that normative diversity and the authority, force, and mutual accountability of those many normative concerns result from the evolution and developmental reconstruction of a discursively articulated, practice-differentiated way of life in the hominin lineage.[8] To complete the outline of a radical naturalism, however, we need to return to the question of its continuity with naturalized philosophies of science.

4 Naturalistic Philosophy of Science Revisited

Naturalized philosophy of science places a double-edged constraint on the viability of any broader meta-philosophical naturalism. First, naturalists can only appeal to "science as we know it" as the basis for philosophical reliance on scientific understanding of the natural world. Second, they must be able to account for the practices and achievements of the sciences we have as themselves a scientifically intelligible natural phenomenon. The second half of *Articulating the World* shows how to situate scientific practice and understanding within its broader meta-philosophical account of human practices and cognitive capacities as evolved and developmentally reconstructed forms of niche construction. In what follows, I call attention to some features of that account that are important for understanding the relation between naturalized philosophy of science and the radical meta-philosophical naturalism it makes possible. This quick summary omits its extensive supporting detail, not only from the book itself, but especially from the extensive work by other philosophers and science studies scholars whose work contributes to a naturalistic conception of scientific practice and understanding. Its aim is only to show how the radical naturalism that extends naturalized philosophy of science satisfies its constitutive double-edged constraint.

A radically naturalistic conception of scientific practice and understanding starts with its two-dimensional normativity. Orthodox and liberal naturalists have primarily attended to only one dimension, namely the justification of scientific knowledge claims. Naturalized philosophy of science brings in a second dimension of scientific normativity, and shows it to be more fundamental to scientific understanding. The determination of which scientific claims ought to be accepted takes place against the background of the articulation, development, and applicability of the sciences' conceptual repertoire, within which those claims are expressed and their deployments inferentially justified. Scientific conceptual articulation is grounded in the experimental, field, and clinical practices for extracting, collecting, preparing, classifying, and working with the *materials* to which scientific conceptualization is accountable. Those practices and skills enable the discernment of conceptually relevant features and boundaries, and secure the objective accountability of those conceptual relationships.[9] Conceptual understanding is then developed in practices of classification, data analysis, inferential articulation and clarification, disciplinary orientation, theoretical modeling, and conceptual revision and refinement that allow particular claims to be formulated and connected to possible justificatory relationships.

What the sciences primarily achieve is the formulation, refinement, extension, and ongoing revision of conceptual relationships. It has been customary to speak of the

[7] Prominent examples of the now-extensive literature on cultural evolution include Richerson and Boyd (2005), Mesoudi (2011), and Tomlinson (2018); Lewens (2015) provides a critical overview.

[8] Rouse (2023) develops an extensive account of the two-dimensional normativity of the discursive, practice-differentiated way of life that has evolved in the human lineage.

[9] "Objective accountability" here refers to how concepts and claims are answerable to the objects, properties, and relations they are about, rather than to any purported criteria for the objective correctness of those claims. For discussion of the difference between these two aspects of objectivity, see Rouse (2015), ch. 5.

historical development of the sciences in terms of the growth of scientific knowledge, but that formulation is misleading. What marks the primary difference between current and earlier scientific capacities is not the replacement of error by truth but development of the ability to speak and reason about aspects of the world that were previously inaccessible and further refinement of those conceptual relationships. The sciences repeatedly open whole domains of reasoned conceptual differentiation: astronomical space, deep time, chemical elements and their molecular bonding and kinetics, electromagnetism, atomic and sub-atomic structures and forces, thermodynamic relations, genetic coding and regulation, tectonic movements, cellular structures and processes, comparative planetary science, organismic metabolisms, climate systematicity, evolutionary descent, ecological interdependences, neural connectivity, microbial life forms and their roles in eukaryotic holobionts, and many more. Scientific understanding of these aspects of the world was mostly preceded by silence rather than error.

Robert Brandom has pointed out that within the conceptual domains opened by such developments,

> [s]orting out who should be counted as correct … is a messy retail business of assessing the comparative authority of competing evidential and inferential claims. … That issue is adjudicated differently from different points of view, and although these are not of equal worth, there is no bird's eye view above the fray of competing claims from which those that deserve to prevail can be identified. (Brandom 1994, 600–601)

What the sciences provide is not a body of knowledge claims certified as correct, but a network of practices, standards, inferential relationships, forms of reasoning, contexts of application, and open questions within which the adjudication of claims is conducted. Moreover, the outcome of that adjudication is a moving target. Amidst the processes of certifying knowledge claims, the conceptual basis of those claims is already being transformed by ongoing research. The experimental practices, assays, or protocols that made those claims intelligible are transformed into instrumental probes or contrastive ground states for articulating further conceptual relationships (Rheinberger 1997, ch. 2). If we want to speak of a Scientific Image of the natural world, it would not be a determinate description but instead a conceptual space of discernment, classification, reasoning, and contestation.

We can now recognize that the further articulation of that conceptual space and the capacities it provides is a doubly mediated process of niche construction (Rouse 2015, ch. 7). Philosophers of science often call attention to the role of diverse models in mediating the application of scientific theory to the world (Giere 1988, Morgan and Morrison 1991, Teller 2001, Weisberg 2013). The concrete situations to which those models are directly applicable, however, are themselves carefully prepared or constructed systems. Those constructed systems include model organisms or organismic tissues as experimental systems; isolated, purified, and shielded interactions of substances, particles, or materials that were methodically extracted from bodies, rocks or soil, oceans, ice cores, or other places; controlled clinical trials; measurement procedures or readings of calibrated instruments. The projectibility of those concepts is not established individually, but only through the open-ended but systematic projection of conceptual domains whose constitutive counterfactual invariance is secured holistically (Lange 2000; Haugeland 1998, 2007; Rouse 2015 ch. 8–10). The reliability of those conceptual relationships and boundaries is secured by the ongoing process of their application and refinement in research and technological development.[10] Moreover, their applicability beyond the research context is then largely enabled by partially extending laboratory materials, procedures, isolation and shielding, and instruments out into the world at large, often in ways simplified or buffered to adapt them to less-controlled conditions (Latour 1983).

One consequence of this account of conceptual articulation is that it challenges both sides of familiar disagreements over the unity or disunity of scientific understanding. Disunifiers rightly emphasize the autonomy of conceptual classifications and reasoning within different scientific domains. Even when entities or processes are understood to be composed of "lower-level" entities or processes, the "higher-level" conceptual relations are often not intelligible at the level of its component processes—if analyzed only at the lower-level, the higher-level classifications would seem arbitrarily gerrymandered. More important, concepts in different domains often have different ranges of counterfactually invariant projectibility: for example, some biological relationships would hold even if their constitutive chemical or physical processes had displayed different patterns of lawful invariance (Lange 2007).

The conceptual autonomy of scientific domains is only partial, however, in two crucial respects. First, they cannot license

[10] The future-directed temporality of the justification of scientific understanding has been a central theme in philosophy of science, although rarely thematized in those terms. Wilfrid Sellars provided one classic expression of this temporal orientation:

> [S]cience is rational not because it has a foundation but because it is a self-correcting enterprise which can put any claim in jeopardy, although not all at once. (1997, 79)

Kuhn (1970) was especially influential in arguing that what secures widespread acceptance of a conceptual orientation is not the retrospective assessment of its coherence and evidential support so far, but its continuing ability to set and solve "problems" for how to extend that conceptualization to new cases, and hence its *promise* as a guide to subsequent research.

conflicting descriptions of actual events or processes; to that extent, they are partially overlapping and mutually accountable conceptualizations of "the" world (Smith 2019, ch. 8–9). Second, their conceptual contentfulness and significance depend on whether the doubly mediated conceptual relationships linking their experimental systems and theoretical models have consequences that matter within other conceptual domains. An entirely self-contained or self-vindicating domain of "conceptual" relationships would be a mere "game," devoid of conceptual content (Rouse 2015, ch. 7, 10). Moreover, the relationships among conceptual and practical domains often bear on the evidential norms at work within any scientific field. As we saw earlier, no empirical findings are without risk of error, and the possible consequences of such errors must figure in assessments of their reliability and evidential support (Douglas 2000; Biddle and Kukla 2017). The normative accountability of diverse conceptual and practical domains are thus firmly linked in unsystematic ways even though there can be no systematic unification of their conceptual relationships and evidential accountability (Rouse 2015, ch. 10).

Scientific research and the conceptual relationships it opens and refines are thus important examples of developmental-evolutionary niche construction. The sciences materially intervene in the world and reconfigure ongoing discursive practices in ways that allow aspects of the world to be newly intelligible. In many familiar cases, they also enable a material infrastructure and the technological transformation of human ways of life and their ecological and geophysical settings. These familiar conceptual and material reconfigurations of the world we inhabit thus exemplify the scientific intelligibility of scientific practices and understanding. A radical naturalism treats language, images, diagrams, and other conceptualizing repertoires as forms of biological niche construction that evolved within the hominin lineage and played significant roles in its anatomical, cognitive, and behavioral evolution. Scientific understanding of the world as "natural" is a further extension of those aspects of people's evolved ways of life. The conceptual articulation of a more complex evolutionary process and evolutionary history of our lineage now enables a more adequate and far-reaching naturalistic self-understanding that can encompass its own conditions of possibility.

Some current advocates of a meta-philosophical naturalism may be motivated by a regulative aspiration to the one true scientific description in a transparent linguistic representation of the world as natural, and may worry that a naturalized philosophy of science undermines that rationale for naturalism in philosophy.[11] A radical naturalism instead recognizes our conceptual capacities and the intelligibility they enable as situated within the world, and incapable of such transcendence of our material involvement. People's conceptual capacities, scientific understanding, social practices, and normative accountability are integral to our evolved and developing lives as environmentally intra-active animals. Recognizing that our social and scientific lives are responsive to our biological needs, opportunities, and resources does not directly determine which scientific judgments or which normative concerns are or should be authoritative or undermine the objective accountability of our conceptualizations and claims. Working out those matters is instead an *ongoing* "messy retail business" of sustaining a normatively complex, practice-differentiated way of life with one another, within an earthly habitat mutually shaped by many biological lineages and a long evolutionary history. A radical naturalism thereby insists that understanding and accountability arise within the natural world and cannot represent or assess it from an imagined position elsewhere or nowhere.[12]

Funding John Templeton Foundation, 61575, Joseph Rouse.

References

Ankeny R, Sabina Leonelli (2016) Repertoires: a post-kuhnian perspective on scientific change and collaborative research. Stud Hist Philos Sci 60:18–28
Armstrong D (1978) Naturalism, Materialism, and First Philosophy. Philosophia 8:261–276
Barad K (2007) Meeting the Universe halfway. Duke University Press, Durham, NC
Barkow J (1992). In: Cosmides Leda, John Tooby (eds) The Adapted Mind. Oxford University Press, Oxford
Bechtel W (2006) Discovering cell mechanisms. Cambridge University Press, Cambridge
Bickerton D (2009) Adam's Tongue. Hill and Wang, New York
Bickerton D (2014) More Than Nature needs. Harvard University Press, Cambridge, MA
Biddle J (2016) Inductive risk, epistemic risk, and overdiagnosis of Disease. Perspect Sci 24:192–205
Biddle J, Kukla R (2017) The Geography of Epistemic Risk. In: Elliott K, Richards T (eds) Exploring inductive risk Case studies of values in science. Oxford Academic, Oxford, pp 215–37
Brandom R (1994) Making it Explicit. Harvard University Press, Cambridge, MA
Brandom R (2000) Articulating reasons. Harvard University Press, Cambridge, MA
Buller D (2005) Adapting minds. MIT Press, Cambridge, MA
Bursten J (2016) Smaller than a breadbox. Br J Philos Sci 69(1):1–23
Buss D (2008) Evolutionary psychology. Routledge, New York
Callebaut W (1993) Taking the naturalistic turn, or how real philosophy of Science is done. University of Chicago Press, Chicago
Cartwright N (1989) Nature's capacities and their measurement. Oxford University Press, Oxford

[11] I am grateful to an anonymous referee for *Topoi* for suggesting the need to address this concern.

[12] The research for this paper has been funded by grant 61575 on "Social Practices, Scientific Practice, and Human Evolution" from the Natural Sciences Division of the John Templeton Foundation, whose support is gratefully acknowledged.

Cartwright N (1999) The Dappled World. Oxford University Press, Oxford
Cartwright N (2007) Hunting causes and using them. Cambridge University Press, Cambridge
Cartwright N (2019) Nature, the artful modeler. Open Court, Chicago, IL
Clarke A, Fujimura, Joan (eds) (1992) The right tools for the job. Princeton University Press, Princeton, NJ
Cowie F (1999) What's within? Cambridge University Press, Cambridge
Davidson D (1980) Essays on action and events. Oxford University Press, Oxford
Caro De (2004) Naturalism in the Philosophy of Mind. In: Macarthur David, Marico c (eds) Naturalism in Question. Harvard University Press, Cambridge
Mario De Caro, Macarthur David (eds) (2010) Naturalism and Normativity. Columbia University Press, New York
De Caro M, Macarthur D (eds) (2022) Routledge handbook of liberal naturalism. Routledge, New York
Dennett D (1991) Real patterns. J Philos 88:27–51
Dor D (2016) The instruction of imagination. Harvard University Press, Cambridge
Dor D, Jablonka E (2000) From cultural selection to genetic selection. Selection 1–3:33–55
Douglas H (2000) Inductive risk and values in Science. Philos Sci 67:559–579
Douglas H (2009) Science, Policy, and the Value-Free Ideal. University of Pittsburgh Press, Pittsburgh, PA
Dupre J (2012) Processes of life. Oxford University Press, Oxford
Elliott K, Richards T (eds) Exploring Inductive Risk. Oxford University Press, Oxford
Fine A (1986a) The shaky game. University of Chicago Press, Chicago
Fine A (1986b) Unnatural attitudes: Realist and Instrumentalist attachments to Science. Mind 95:149–179
Fine A (1991) Piecemeal realism. Philos Stud 61(1–2):79–96
Fine A (1996) Science Made Up: Constructivist Sociology of Scientific Knowledge. In Galison and Stump 1996, 231–54
Galison P (1996) Image and logic. University of Chicago Press, Chicago
Galison P, and Stump, David (ed) (1996) The disunity of Science. Stanford University Press, Stanford, CA
Giere R (1985) Philosophy of Science Naturalized. Philos Sci 52:331–356
Giere R (1988) Explaining Science. University of Chicago Press, Chicago
Giere R (1999) Science without Laws. University of Chicago Press, Chicago
Giere R (2006) Scientific perspectivism. University of Chicago Press, Chicago
Goodman N (1954) Fact, fiction, and Forecast. Harvard University Press, Cambridge, MA
Hacking I (1983) Representing and intervening. Cambridge University Press, Cambridge
Hacking I (1992) The self-vindication of the laboratory sciences. In: Pickering A (ed) Science as Practice and Culture. University of Chicago Press, Chicago, pp 29–64
Hacking I (2009) Scientific reason. National Taiwan University Press, Taipeh
Haugeland J (1998) Having thought. Harvard University Press, Cambridge, MA
Haugeland J (2007) In: Crowell S, Malpas J, Heidegger T (eds) Letting be. Stanford University Press, Stanford, CA, pp 93–103
Haugeland J (2013) Dasein Disclosed. Harvard University Press, Cambridge, MA
Hempel C (1965) Aspects of scientific explanation. Free Press, New York
Jackson F (1998) From Metaphysics to Ethics. Oxford University Press, Oxford
Kitcher P (2001) Science, Truth and Democracy. Oxford University Press, Oxford
Kuhn T (1970) The structure of Scientific Revolutions. Second Edition. University of Chicago Press, Chicago
Kukla R (2008) Medicalization, 'Normal function', and the definition of Health. In: Arras J, Fenton E, Kukla R (eds) The Routledge companion to Bioethics, xxx-xxx. Routledge, New York
Laland K (2017) Darwin's unfinished Symphony. Princeton University Press, Princeton, NJ
Laland K, Brown G (2011) Sense and non-sense. Second edition. Oxford University Press, Oxford
Lange M (2000) Natural laws in scientific practice. Oxford University Press, Oxford
Lange M (2002) Who's afraid of Ceteris Paribus Laws? Or how I learned to Stop Worrying and Love them. Erkenntnis 57:407–423
Lange M (2007) Laws and Theories. In: Sarkar Sahotra, Plutynski Anya (eds) Companion to the Philosophy of Biology. Blackwell, Oxford, pp 489–505
Latour B (1983) In: Knorr-Cetina K, Mulkay M, eds., Observed S (eds) Give me a laboratory and I will raise the World. London: Sage, 141–70
Leonelli S (2016) Data-Centric Science. University of Chicago Press, Chicago
Lewens T (2015) Cultural Evolution. Oxford University Press, Oxford
Lewontin R (2000) The Triple Helix. Harvard University Press, Cambridge, MA
Lloyd E (2008) Science, Politics, and evolution. Cambridge University Press, Cambridge
Macarthur D (2010) Taking the Human Sciences Seriously. In De Caro and Macarthur 2010, 123–41
Maynard-Smith J (1978) Optimization theory in evolution. Annu Rev Ecol Syst 9:31–56
McDowell J (1994) Mind and world. Harvard University Press, Cambridge, MA
Mesoudi A (2011) Cultural Evolution. University of Chicago Press, Chicago
Mills S, Beatty J (1979) The Propensity Interpretation of Fitness. Philos Sci 46:263–286
Mitchell S (2009) Unsimple truths. University of Chicago Press, Chicago
Morgan M, Morrison M (eds) (1996) Models as mediators. Cambridge University Press, Cambridge
Nersessian N (2008) Creating scientific concepts. MIT Press, Cambridge, MA
Okrent M (2007) Rational animals. Ohio University Press, Athens, OH
Okrent M (2017) Nature and Normativity. Routledge, New York
Papineau D (2021) Naturalism. The Stanford Encyclopedia of Philosophy (Summer 2021 Edition), Edward N. Zalta (ed). <https://plato.stanford.edu/archives/sum2021/entries/naturalism/>.
Pickering A (ed) (1992) Science as Practice and Culture. University of Chicago Press, Chicago, IL
Price H (2011) Naturalism without mirrors. Oxford University Press, Oxford
Quine WvO (1969) Ontological relativity and other essays. Columbia University Press, New York
Reardon J (2005) Race to the Finish. Princeton University Press, Princeton, NJ
Reardon J, Metcalf, Jacob K, Martha, and, Barad K (2015) "Science & Justice: The Trouble and The Promise" Catalyst 1(1):1–48
Rheinberger H-J (1997) Towards a history of Epistemic Things. Stanford University Press, Stanford, CA
Richerson P, Boyd R (2005) Not by genes alone. University of Chicago Press, Chicago

Rouse J (1987) Knowledge and power. Cornell University Press, Ithaca, NY
Rouse J (1996) Engaging Science. Cornell University Press, Ithaca, NY
Rouse J (2005) Epistemological derangement. Stud Hist Philos Sci 36:835–847
Rouse J (2015) Articulating the World. University of Chicago Press, Chicago, IL
Rouse J (2022) Liberal or Radical Naturalism? In De Caro and Macarthur 2002.
Rouse J (2023) Social Practices as Biological Niche Construction. University of Chicago Press, Chicago, IL
Sellars W (1957) Counterfactuals, dispositions, and the Causal Modalities. In: Feigl H, Scriven M, Maxwell G (eds) Concepts, theories, and the mind-body problem. University of Minnesota Press, Minneapolis, MN, pp 225–308
Sellars W (1997) Empiricism and the philosophy of mind. Harvard University Press, Cambridge, MA
Sellars W (2007). In: Scharpp K, Brandom R (eds) The space of reasons. Harvard University Press, Cambridge
Smith BC (2019) The promise of artificial intelligence. MIT Press, Cambridge
Solomon M (2015) Making medical knowledge. Oxford University Press, Oxford
Sterelny K (2003) Thought in a hostile world. Blackwell, Oxford
Sterelny K (2012) The Evolved Apprentice. MIT Press, Cambridge
Tallbear K (2013) Native american DNA. University of Minnesota Press, Minneapolis
Teller P (2001) Twilight of the Perfect Model Model. Erkenntnis 95:393–415
Tomasello M (2008) Origins of Human Communication. MIT Press, Cambridge, MA
Tomasello M (2014) A natural history of human thinking. Harvard University Press, Cambridge, MA
Tomasello M (2019) Becoming human. Harvard University Press, Cambridge, MA
Tomlinson G (2015) A million years of music. Zone Books, New York
Tomlinson G (2018) A Cultural history of human evolution. University of Chicago Press, Chicago, IL
Warwick A (2003) Masters of theory. University of Chicago Press, Chicago, IL
Weisberg M (2013) Simulation and Similarity. Oxford University Press, Oxford
Wilson EO (1975) Sociobiology. Harvard University Press, Cambridge
Wilson M (2006) Wandering significance. Oxford University Press, Oxford
Winsberg E (2010) Science in the age of Computer Simulation. University of Chicago Press, Chicago
Winsberg E (2018) Philosophy of Climate Science. Cambridge University Press, Cambridge
Woodward J (2021) Causation with a Human Face. Oxford University Press, Oxford
Woody A (2004) Telltale Signs. Found Chem 6:13–43
Wylie A (2002) Thinking from things. University of California Press, Berkeley, CA