Natural Kinds for the Scientific Realist

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(in *The Routledge Handbook of Scientific Realism*. Juha Saatsi, ed. Routledge Publishers, 2018)

1. Introduction

To a first approximation, natural kinds are the objects of successful scientific classification. When physicists announced the discovery of the Higgs Field Boson, for example, they were announcing their discovery of a natural kind of thing (or phenomenon) whose properties were roughly as predicted by physical theory. This was a notable confirmatory success of the dominant model of particle physics: the world seemed to be structured as the theory said it was. Examples like this abound in the natural sciences. We often apparently discover new kinds of things or new facts about known kinds and we sometimes improve on our classifications by discovering that our concepts and categories did not correspond to the structure of reality as we thought it was. Thus, for Scientific Realists, the notion of a natural kind can play an important role in the philosophical picture of how our scientific theories related to an objective, mind-independent world.

2. Naturalness

The concept of a natural kind has a long and contentious pedigree, but the basic idea can be illustrated by thinking about some contrasts. The first contrast is between individual things and *kinds* of things. Here's a panda; there's another panda. What do they have in common? Many things, perhaps; but the most salient response is that they are both of the same *kind* – they're both *pandas*. We thus organize a lot of our thought and talk by dividing things up into different conceptual categories. The sciences in particular are rife with such efforts to divide the world into categories – more on this soon. But the sciences are not alone in this.

Here we encounter a second contrast. Consider the classic films "Psycho" and "The Silence of the Lambs"; like our pandas, these individuals can be placed in a few common categories: they are both "thrillers", they are both R-Rated movies, and so on. But there appears to be an important difference between the kinds *thrillers* and *pandas*. Only the latter is a *natural* kind – a category with some objective existence – the former appears to be a byproduct of our more or less arbitrary way of dividing up the world.

There are a number of ways we might try to draw this second distinction. One strategy might use scientific attention. ‘Thriller’ does not name a scientific category; ‘panda’ does. On further reflection, however, this idea seems problematic. Are we talking about actual or merely possible scientific attention? The former is clearly too conservative — at least for a scientific realist — in that we often take science to be in the business of *uncovering* preexisting divisions in nature. Pandas were a natural kind (if they in fact are a natural kind) before anyone had seen a panda. The latter strategy of seeing naturalness as dependent on what science *could* find interesting is more tempting, but it is difficult to work out precisely. Are we really so sure that future psychologists might not formulate scientific theories that involved thrillers as important categories (say, in their capability of producing certain physiological/emotional responses in us)?[1]

Another suggestion would be to focus on the sense that thrillers are artifacts: they’re things that people *make*, not items in the “natural world”. Whereas in science we speak comfortably of discovering new kinds of things — pandas, electrons, typhoid — it’s at least pretty strained to think of ourselves (or humanity) as “discovering” thrillers. We *invented* them. But here too the distinction is not as clean as paradigm cases suggest. Some chemical elements and materials — such as the element technetium or the patented material Kevlar® — are human artifacts in the sense that they do not exist in nature but by our intervention. Yet despite needing to be produced in a laboratory, they seem just as much to be natural kinds as *gold* or *hydrogen* in the role they play in science (LaPorte 2004; Hacking 2007a, 204).[2]

What is the role that natural kinds play in science, then? This is a bigger question that we will need to address piecemeal over this chapter, but starting on it provides a third gloss on what makes a kind *natural*. Scientific theories often purport to describe *general* features of of the world. This is most obvious when the sciences are at their most ambitious: uncovering laws of nature. For example, the law that electrons have a charge of -1.6×10^{-19} coulombs is a description not just of a sample of electrons studied in a lab in Chicago, but of *all* electrons — of the *kind* electron. Given further laws

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[1] Indeed, as I think about it, I can’t say I’m confident that they *haven’t*. Perhaps this just means that *thriller* doesn’t in fact represent a good contrast with *panda*. But even for more obvious contrasts — say *gourmet crackers* or *the items currently sitting on my desk* — anyone with even a meagerly-developed philosophical imagination could probably cook up some far out scenario where an obscure and perhaps misguided science takes a shine to even such obviously subjective or gerrymandered categories.

[2] One response to this observation might simply be to drop the ‘natural’ modifier and follow philosophers like Whewell (1840) or Mill (1872) in speaking of ‘real kinds’ or simply ‘Kinds’. For helpful histories, see Hacking (1991) and Magnus (2014). Though a question would still, of course, remain of how to distinguish such Kinds from miscellaneous categories.

governing the ways that charges relate to forces, a physical theory enables understanding and prediction of how electrons will interact with other kinds of particles. There is thus a straightforward sense in which many scientific theories are *about* kinds of things — or processes, events, properties, and so on more generally — by being in the business of producing a certain kind of generalized knowledge. And this is one of the reasons why we are inclined to think of technetium as a natural kind, despite the fact that it is a human artifact: we can determine laws of nature that govern how samples of technetium behave such that when a different quantity of it is produced for the first time in another lab, we rightly bring to the table some robust expectations for how it will behave.

While this gloss on what it is to be a *natural* (rather than socially-constructed) kind might work for physical kinds, it is contentious whether natural kinds should be thought as the subject-matter of natural laws (Kitcher 1984, 315—316; Lange 2000, 210). As we will see below, there are other ways of identifying the role of natural kinds in science (or in systematic inquiry more generally) that do not require the tight connection with laws — something that will come as welcome news to those who wish to view species as natural kinds and who yet doubt that biological taxa are governed by distinctively biological laws (Beatty 1995; Rosenberg 2001; cf. Lange 2004). Ditto for many of the special sciences — even social sciences — where laws play little role.

However we work this out precisely, the idea of natural kinds' "mind-independence" will loom large. And here we can draw a useful distinction between *causal* independence from human activity and *conceptual* independence which may help resolve some of the puzzles about naturalness. The existence of technetium or Kevlar or perhaps of social kinds (like races and refugees) are causal artifacts of human activity. They are, to use a once-trendy phrase, social constructions, as are the systems of classification we use to sort them into categories. But once made, even the social world has an existence that is to some degree independent of our thought and talk. So says the Realist — to whom we now turn.

3. Scientific Realism and Realism about Kinds

The core of Scientific Realism is a general and commonsensical thesis: there's the world and then there's us; the features of the world enjoy a substantial independence from our thought and talk about them. In other words, we don't make the world what it is by merely forming beliefs about it.[3]

[3] This view (or something like it) has also been called Metaphysical Realism and has been somewhat difficult to characterize precisely; see Putnam's many writings (e.g., his 1981) and Khlentzos (2011) for discussion of the controversies surrounding it which I will largely ignore in this chapter.

Of course, as we discussed above, we can certainly influence the world — causally, by altering it, or just in the sense that human beliefs are part of the world. Peter Godfrey-Smith encapsulates this thought into his sophisticated version of Realism:

> *Common-sense Realism Naturalized*: We all inhabit a common reality, which has a structure that exists independently of what people think and say about it, except insofar as reality is comprised of thoughts, theories, and other symbols, and except insofar as reality is dependent on thoughts, theories, and other symbols in ways that might be uncovered by science. (2003, 176)

This amounts to the thesis that science has a potential subject matter. The world — including those aspects of reality that are comprised of or influenced by our thoughts — exists for us to investigate; moreover, the thesis that the world has a repeatable *structure* is part of what makes it tractable for science to to investigate. The success of science, in this sense, might be thought to *depend* on there being natural kinds for our scientific theories to latch onto.

So far, so good. But the Scientific Realist will need to go further. The degree to which this reality is independent of our thought and talk raises the possibility that the descriptions stemming from these investigations may be mistaken. What stance should we take on this matter? The Scientific Realist is optimistic, suggesting that it is a reasonable goal of science to uncover facts about reality. This optimism is generally founded in the sense that recent scientific theories have enabled an extraordinary degree of success at predicting and controlling a world that we did not make. On this view, mature scientific theories can reasonably be taken to provide accurate descriptions of reality. Of course, this is not to say that science is infallible or even that it is in a position to report on the whole of reality (whatever that would mean). Scientific Realists must temper their optimism with the knowledge that plenty of scientific theories have fallen by the wayside — a fact to which we will return in the next section.

Thus, we may think of Scientific Realism as being comprised by two main tenets: the metaphysical thesis about the existence of a largely independent reality with a tractable structure discussed above and an epistemic thesis concerning the proper attitude we should have concerning the sciences' access to this reality. To these, a third, semantic, thesis is sometimes added: that mature scientific theories consist, in part, in literal descriptions of the world. As Psillos puts it, the Scientific Realist

> takes scientific theories at face-value, seeing them as truth-conditioned descriptions of their intended domain, both observable and unobservable. Hence, they are capable of being true or false. Theoretical assertions are not reducible to claims about the

> behaviour of observables, nor are they merely instrumental devices for establishing connections between observables. The theoretical terms featuring in theories have putative factual reference. So, if scientific theories are true, the unobservable entities they posit populate the world. (1999, xvii)[4]

The metaphysical and semantic components of Scientific Realism establish a prima facie connection with the concept of natural kinds. Taking scientific theories at face-value involves accepting their claims about *classes of things* as true descriptions of reality. So, to return to our previous example, when a mature and successful theory refers to the properties of electrons, the Realist accepts that there really is this kind of thing, independent from our theorizing, with properties described by the theory. Indeed, in Psillos's telling, the metaphysical thesis *focuses* on natural kinds, asserting "that the world has a definite and mind-independent natural-kind structure" (*ibid*.).

Enthusiasts of natural kinds have appropriated a famous metaphor from Plato that captures this idea (*Phaedrus*, 265e). When scientists are engaged in the business of discovering and characterizing different kinds of things, we might think of them in the model of butchers parceling up an animal. Good butchers, it is said, keep their knives sharp by cutting only at the joints, the physiological discontinuities. Reality, in this metaphor, is like the animal under the knife. It features natural discontinuities along which our best scientific theories may "carve"; in doing so, they truly describe the world. By contrast, when the sciences have invoked categories such as "aether", "phlogiston", or "caloric" — substances that did not in fact correspond to any natural discontinuities — they erred. They *missed* the natural discontinuities, sawing with difficulty through "reality's bones".

Plato's metaphor and talk of the "structure of reality" plainly evoke realism about natural kinds. And it seems natural for a realist about natural kinds to accept the broad metaphysical and semantic commitments associated with Scientific Realism.[5] Must they accept the epistemic commitment? This is not as clear. One might, after all, accept that reality has some independent natural kind structure without evincing much optimism that we are very good at uncovering it. Of course, it may seem strange to adopt anything more than agnosticism about the reality of natural kinds if one doubted

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[4] Some might prefer a more lenient "accuracy" condition in order to make room for idealization and other standards of success in the sciences' representation of reality (see, e.g., Godfrey-Smith 2003, 176–177; Elgin 2004). I set this matter aside in the present discussion.

[5] Laudan makes the connection to the semantic dimensions of Scientific Realism this way: "To have a genuinely referring theory is to have a theory which 'cuts the world at its joints', a theory which postulates entities of a kind that really exist" (1981, 24).

that science routinely traded in accurate descriptions of reality in both its observable and unobservable aspects; but it is a logical possibility.

What about the reverse direction? Do the metaphysical and semantic commitments of Scientific Realism *demand* that we accept Realism about natural kinds. This issue is more complex, turning on nuances of our conception of the Scientific Realist's theses and our precise understanding of what natural kinds are. We will explore some of these issues in more detail in a later section, but for now we can illustrate at least the localized possibility of a Scientific Realist disavowing natural kinds by considering the debates over the metaphysical status of biological species.

I used the example of pandas previously to illustrate the concept of a natural kind. But an influential account of species took root in the 1970s that rejected the thesis that species were natural kinds at all. Reacting, in part, against the idea that natural kinds could be given precise membership conditions — that there was an *essence* to being, say, a panda — the biologist Michael Ghiselin and philosopher David Hull proposed that species were instead *individuals* — particular, concrete objects. Similarity, they say, is a red herring when it comes to systematics; and natural kinds are all about similarity.[6] Rather than possessing certain intrinsic properties that made some organisms pandas, what they shared was simply a connection to a particular chunk of the tree of life (Ghiselin 1974; Hull 1978). And insofar as the tree of life has an existence and topology independent of our classificatory whims, the species-as-individuals metaphysics would appear to be fully compatible with the commonsense realism described above.

It would seem at first, then, that the advocate of species-as-individuals can accept all three tenets of Scientific Realism without committing herself to natural kinds. Much of what science does is concerned with learning about particular things, rather than kinds of things. It remains to be seen, however, whether such commitment can be avoided more broadly. After all, in the course of doing the biology and paleontology needed to discern the structure of the history of life, it is plausible that reference to natural kinds of at least the physical or chemical sort will be common. But however this may be, it illustrates that there is at least *some* independence between realism about natural kinds and Scientific Realism.

[6] Quine (1969) thought that this is what would make natural kinds ultimately dispensable in general, as vague notions of overall similarity would ultimately give way to more specific notions from the relevant sciences or be eliminated altogether. The philosophical collective wisdom has not followed him to this extreme.

4. A Challenge to science realism and realist responses

One of the central arguments against scientific realism begins from the observation that our present scientific theories are built upon the ruins of yesterday's. As Larry Laudan puts it in an influential article, "what the history of science offers us is a plethora of theories which were both successful and (so far as we can judge) non-referential with respect to many of their central explanatory concepts" (1981, 33). Interesting for our purposes is the fact that many of these concepts purport to refer to kinds of stuff. Laudan mentions the humoral theory of medicine, effluvial theory of static electricity, phlogiston, caloric, and the optical aether (*ibid*.). The invited conclusion of this argument — what has come to be called the "pessimistic induction" — is that we should not be as impressed as the Realist suggests about the success of our current scientific theories. After all, previous investigators might have offered the same argument for scientific realism concerning caloric, etc. This appears to give us reason for doubting that we are in any better epistemic situation; we might even suspect that our theories will be just one more stratum in history's deposit of ruined theories. (See P. Vickers, "Historical challenges to realism," ch. 4 of this volume.)

Notice that this argument focuses on the epistemic tenet of Scientific Realism, leaving unscathed the metaphysical tenet. An anti-realist of Laudan's stripe need not deny that we live in a common reality largely independent of our thoughts; she simply argues that history gives us reason to doubt the ability of our sciences to provide us with accurate descriptions of the fundamental aspects of this reality. She holds that the Scientific Realist is inappropriately optimistic.[7] However, this pessimism does have consequences for the semantic tenet of Scientific Realism. We have already cited substance terms like "caloric" and "phlogiston" as foils for natural kinds. But unlike terms like "gourmet multigrain cracker", which presumably no one has ever supposed referred to a natural kind, phlogiston *was* treated as a scientifically-important kind of stuff — a putative natural kind. So it looks like the anti-realist's doubt about the status of our scientific theories as literally true descriptions of the world leads to a corresponding doubt that our present natural kind terms carve nature at the joints either.

There is much to say about this argument, of course; but in the present context, it is worth considering two sorts of responses. One response involves seeking continuity through reference to

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[7] As usually understood, the pessimistic induction generalizes from the history of past theories to our own present-day theories. In Kyle Stanford's (2006) "Problem of Unconceived Alternatives", by contrast, the induction ranges over past theor*ists*, pointing to the conclusion that we are no better than they were in being able to conceive of all relevant alternative explanations of natural phenomena between which to choose. See also K. Stanford, "Unconceived alternatives, and uniformitarian instrumentalism," ch. 17 of this volume.

natural kinds. We turn to this response in the next section, using it as a springboard for discussing the metaphysics of natural kinds. A second response seeks continuity in the *mathematical structures* of theories as they change, possibly at the cost of relinquishing reference to natural kinds and other unobservables in order to preserve a kind of continuity through scientific change. Consider, for example, the transition from wave optical theories that postulated a physical medium — the *luminiferous aether* — through which light travelled to Maxwell's electromagnetic theory which dispensed with this medium. On the one hand, this was a rather significant change. The theory of light was no longer about how a certain stuff moved; indeed, it repudiated the existence of the stuff altogether. But on the other hand, the mathematical formalism describing how light behaved remained remarkably constant. Similar comments can be applied to thermodynamics and *caloric* (Kitcher 1992).

This strategy — *Structural Realism* — was introduced by John Worrall (1989) and has since been developed in various flavors.[8] In the *epistemic* flavor, generally attributed to Worrall, Structural Realism concedes to the anti-realist that optimism in the sciences' ability to tell us about the underlying nature of reality is misplaced. Worrall thus rejects "standard scientific realism". But again, this epistemic stance implies nothing about what natural kinds in fact exist. Ontic Structural Realism, on the other hand, represents a radical metaphysical claim with epistemic consequences: that "realists should believe only in structures described by our best theories because structure is all there is to reality….The usual talk of objects, they say, is misguided, and engenders fatal metaphysical difficulties. Ontic structuralists are happy to speak of objects, but only as a *façon de parler*, not to be taken literally" (Chakravartty 2007, 70–71). At first glance it might seem as though the prospects for a metaphysics of natural kinds might fare no better than objects. After all, how can there be *kinds of things* without *things?* And indeed, Ladyman and Ross, advocates of Ontic Structural Realism, suggest that we should "give up the idea that science finds its metaphysical significance in telling us what sorts of things there are" (2007, 93). But it may be possible nevertheless to reconceive an account of natural kinds to accord with structuralist scruples.[9] Chakravartty is more optimistic that Structural Realism may be wedded to an ontological picture that includes natural kinds as clusters of causal properties. In this, the realist is merely attempting to make sense of what seems to be "an important feature of what realists take to be a mind-independent

[8] For an overview, see Ladyman's (2014) entry in the *Stanford Encyclopedia of Philosophy,* and I. Votsis, "Structural realism and its variants," ch. 7 of this volume.

[9] See Ladyman and Ross (2007, 291) for some suggestive discussion on this front.

reality": that properties are not "randomly distributed across space-time"; they are "sociable" in systematic ways (2007, 170). As we'll see, this sort of "cluster" approach has been an important way of thinking about kinds in scientific domains that do not seem to admit of as much law-governed order as physics and chemistry.

5. Realism Concerning Natural Kinds

Let us take a step back. What is so useful about "cutting nature at the joints", supposing that there are any such joints? Why should we care? One response is that doing so is simply part and parcel of doing science. This may have been what Hempel had in mind when he wrote of the two basic functions of the "vocabulary of science": first, "to permit an adequate description of the things and events that are the objects of scientific investigation"; and second, "to permit the establishment of general laws or theories by means of which particular events may be explained and predicted and thus scientifically understood; for to understand a phenomenon scientifically is to show that it occurs in accordance with general laws or theoretical principles" (1965, 139). So it is in that way, as Ladyman and Ross put it, that "the concepts of '(natural) kind' and 'law' are yoked together, on the general supposition that natural kinds are what laws are true of" (2007, 290).

Another response has it that accommodating our inferential and explanatory practices to the "causal structure of the world" — in part by attuning our categories to the natural kinds — is crucial to our success in these practices (Boyd 1991; Kornblith 1993; Sankey 1997; Godfrey-Smith 2011). An especially deflationary version of this idea commits to little else about natural kinds, electing to treat them more or less as epistemic categories (we will consider this approach to natural kinds in the final section). But the concept of a natural kind reentered philosophical discussion in the 20th century via a "middle-of-the-road" strategy that packaged ideas about the metaphysics of natural kinds — what reality's "joints" *are* — together with a developing theory of how to refer to them. Here I will only sketch the highlights of this oft-told (contested) story as they bear on the connection to Scientific Realism (for details, see, e.g. Hacking 1991).

Let's start with reference. How do proper names refer to their objects? On one account — *Descriptivism* — reference is secured by some unique description associated with a name. So, for example, the name 'Aristotle' might be associated with the description 'Plato's most distinguished pupil'. But as Kripke pointed out, Descriptivism has odd consequences when we consider certain modal questions about Aristotle: for example, *could Aristotle have studied sculpture instead of philosophy?* At first blush, the obvious answer is 'yes'; but if we *define* Aristotle as Plato's most distinguished (philosophical) pupil, we seem forced to treat it as a trivial, linguistic truth that Aristotle studied philosophy — something that could not have been otherwise. That's quite implausible; of all people, Aristotle could have pursued all manner of careers.

To accommodate these and other intuitions about how names work in merely possible or epistemically imperfect situations, Kripke pressed an alternative view that used descriptions incidentally (if at all). Reference, he argued, was better treated as a *direct* matter (Kripke 1980). Someone pointed to Aristotle and said something like (and I translate) "Let's call him Aristotle" and thereby named a certain baby 'Aristotle'. That usage has been transmitted down to us by a causal chain in such a way that we could be completely mistaken about our descriptions of Aristotle and still successfully refer to *that person*. In contrast, if names refer exclusively via descriptions, errors in description become errors (or outright failures) in reference.

We can see this same dynamic play out in the case of natural kind terms. How do they refer to natural kinds? Descriptivism is perhaps more tempting in this domain, as characterizing the kinds of things in the world is a major part of what science does. But it also seems plausible that we can successfully refer to a certain kind of stuff (say) before we begin any kind of systematic attempt to characterize it, in more or less the same manner that we can start using a proper name like 'Aristotle' to name a screaming child whose philosophical pedigree and acumen is as yet unknown. Moreover, even when we have a rough and ready description associated with a kind of stuff — for example, that water is clear, potable, a good solvent, that stuff that flows in streams and rivers, and so on — Putnam argues that we can conjure intuitions that this description may not apply to all (liquid) water and might in fact apply to a kind of stuff that is chemically completely different from actual water.[10] What matters is whether a given sample is of the same kind as the stuff that was initially "baptized" as water: "A term refers to something if it stands in the right relation (causal continuity in the case of proper names; sameness of "nature" in the case of kinds terms) to these [gestured-at] things" (Putnam 1983, 73). This is the Causal Theory of Reference. Its intuitive appeal rests in part on the sensibility of a distinction between knowing that there is something to which a term refers (by dint of pointing at it and *naming* it) and understanding the nature or *essence* of that something (Psillos 1999, 273).

[10] The famous example of "Twin Earth" is discussed in Putnam (1975); for more on this thought experiment and discussion of some of the specific contentions Putnam makes about the definition of water, see P. Needham, "Scientific realism and chemistry," ch. 27 of this volume.

Drawing this distinction, and allowing an underlying metaphysics of sameness of "nature" or kind to do much of the work in allowing us to refer back to new instances or samples of the same stuff or kinds, brings us back to the second response to Laudan's pessimistic induction argument. The problem the Scientific Realist faced, recall, was to make sense of the dismal history of empirically successful scientific theories that were nevertheless incorrect or referentially unsuccessful. But if natural kind terms find their reference in accordance with the Causal Theory, it looks like we can make sense of changing (improving) descriptions of the same natural kinds through even major scientific changes. Psillos summarizes this line of thought this way:

> The causal theory lends credence to the claim that even though past scientists had partially or fully incorrect beliefs about the properties of some causal agent, their investigations were continuous with investigations of subsequent scientists, since their common aim has been to identify the nature of the same causal agent…. Insofar as successor theories afford better descriptions of the same causal agent and its relations with other causal agents, one can conclude that science has improved our understanding of the world. And insofar successor theories are more truth like than their predecessors in their descriptions of the nature of these causal agents, one can argue that science has achieved a better approximation to the objective causal structure of the world. (1999, 273–274)

This points to a further way of making sense of the Realist idea that we inhabit a common, objective reality that we can refer to and describe in a variety of ways. The great evolutionary biologist Ernst Mayr was fond of citing evidence of convergence in classificatory systems across cultures as justification for the reality of biological species, writing: "Nothing convinced me so fully of the reality of species as the observation…that the Stone Age natives in the mountains of New Guinea recognize as species exactly the same entities of nature as a western scientist" (1987, 146). Even if we offer different descriptions of these taxa from naturalists working in different traditions, we can make sense of our referring to the same kinds.

Unfortunately, there are a number of difficulties and unanswered questions for this strategy. One class of difficulties concern the methodology employed in motivating the Causal Theory in the first place. Putnam relies fairly heavily on intuitions about difficult to imagine scenarios — e.g., that 'water' would not refer to a substance with a different underlying structure which played an identical superficial, causal role on "Twin Earth" (see Putnam 1975). But are we really so sure that this is the right thing to say (Mellor 1977; Dupré 1993)? There are also difficulties getting the Causal Theory to work right. Pointing is ambiguous, even when it's obvious to which *object* I am intending to name. Suppose we are birding with Mayr and he points to a particular bird, naming it; has he named a species, a genus, a sub-species, a variety, an order?[11]

Setting aside these questions, there is also a question of whether the Causal Theory enables a plausible and satisfactory rejoinder to the Pessimistic Induction. It might seem like cold comfort for the Scientific Realist if all that remained constant through radical theory change was the fact that we continued to talk about the same kinds, despite being at times radically wrong about their nature (Stanford 2003). This would offer little in the way of assurance, after all, that our current theoretical understanding of these kinds is sound — presumably something that a Realist wants. It can also seem like the Causal Theory of reference is implausibly strong. Consider 'phlogiston', introduced by the causal description of *that gas (whatever it is) causally-involved in combustion.* In contrast with the development of theory surrounding, e.g., water, electrons, and such, its introduction was entangled with a conspicuous amount of mistaken chemical theory. Granted, Joseph Priestley and the other chemists investigating the phenomena of combustion were causally related to oxygen; as Psillos puts it, "they breathed it and it was causally involved in the experiments they made to investigate combustion". But the properties that oxygen in fact has were not causally associated with the theory associated with phlogiston (Psillos 1999, 280–281). To get things right, argues Psillos, we must draw upon theoretical descriptions of what sorts of properties are relevant in fixing the reference of a particular term. Exactly what parts of a scientific theory should determine this in general (without backwards-looking ad hocery) remains a matter of continued discussion (Stanford 2003; McLeish 2006).

Let us turn now to the metaphysics of natural kinds and its connection to theories of reference for natural kind terms. One way of thinking about Putnam and Kripke's approach to natural kind terms (cf. Hacking 2007b) is as a revival of the Lockean distinction between nominal and real essence (Locke 1689/1975). Nominal essences are the descriptions associated with a term (which may be inconstant or about which we might just be wrong); the real essence is the *nature* of the kind itself — the properties which determine what it is to *be* a thing of that kind. What is it that makes this glass of water the same stuff as the stuff flowing in that clear stream? Putnam's answer (picking up on a quick suggestion of Quine 1969): the fact that they share the same underlying structure — something that modern chemistry is in a position to report on. Moreover, it is this structure, presumably, the "binds together" the properties figuring in water's nominal essence. This suggests a

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[11] For discussion of these sorts of difficulties, see Devitt and Sterelny (1987, 72–75), Stanford and Kitcher (2000), and LaPorte (2004).

metaphysics of natural kinds focusing on microstructural or otherwise fundamental features of reality.

This view came to be called Scientific Essentialism (Bealer 1987) and is sometimes thought to provide a "metaphysic of scientific realism" (Ellis 2001, 2). There are a number of difficulties with this view that we cannot properly survey here, except to point out that one of the major problems facing the Essentialist is the difficulty in applying the sorts of strict, microstructural approaches to real essences that apparently worked for physical and chemical examples, to biological kinds such as species, as these seemed to defy simple individuation on the basis of a shared "genetic structure" as Putnam posited (see, e.g., Wilson 1999, 190).[12] In the next section, we will briefly examine approaches to natural kinds that take a more flexible approach designed to reflect their deployment across a wider range of scientific disciplines.

6. Cluster Approaches to Natural Kinds

One response to the difficulties in application of the essentialist approach simply drops the ambition of construing biological or social categories as natural kinds at all. As mentioned above, realists about species have a ready alternative: treat species taxa as individuals. But this strategy is not workable for other biological examples, such as cells and biological macromolecules. Yet we have ample reason for wanting to think of all of these categories as natural kinds in virtue of their contribution to our inferential and explanatory practices (Slater 2009, 2013b).

Accordingly, non-essentialist approaches to natural kinds have been popular among philosophers of biology. Rather than seeking properties strictly shared by all and only the members of a given kind, one might follow Boyd (1991, 1999) in thinking of natural kinds instead as *clusters* of properties that tend to co-occur together (Chakravartty 2007, 170). The allowance for imperfection in clustering is a key element in how this Homeostatic Property Cluster (HPC) account of natural kinds can be seen to apply to the messy and exception-ridden biological world (Wilson *et al.* 2007). The issues surrounding the metaphysics of HPC kinds get complex fast, however. In the case of essentialist kinds, it was relatively easy to think of natural kinds as certain kinds of intrinsic universals: e.g., *the property of having the molecular structure represented by the chemical structure 'H2O'*. It's less obvious what sorts of things *clusters* are or what sorts of properties can constitute

[12] For contrasting views, see Wilkerson (1995) and Devitt (2008); Slater (2013a) discusses alternative metaphysics of species that either abandon or modify essentialism about natural kinds.

them; nor is it clear that the Scientific Realist needs to alight on a specific metaphysical approach here in order to explain the success of science.

To some extent, such agnosticism played a role in the early formulation of the HPC theory. A key idea for Boyd is what he calls the Accommodation Thesis: "the theory of natural kinds is about how schemes of classification contribute to the formulation and identification of projectible hypotheses…. [W]hat the representation of phenomena in terms of natural kinds makes possible, is the accommodation of inferential practices to relevant causal structures" (1999, 147). According to Boyd, these causal structures are the "homeostatic mechanisms" that maintain the coherence of a cluster of properties. At first glance, anyway, a Scientific Realist should find much to like in Boyd's account. For we have at least the makings of a robust account of how scientific investigation is related to the structure and patterns in the world without a significant amount of airy metaphysics.

But once again, there are open questions about how much metaphysics is enough here. Some philosophers of science and metaphysicians are inclined to push further into the metaphysics of causal properties (see Chakravartty 2007; Hawley and Bird 2011). Others have gone in the opposite direction, downplaying the precise metaphysics of natural kinds, and emphasizing instead their epistemic role(s) in scientific inquiry. Khalidi, for example, adopts what he calls a Simple Causal Theory of natural kinds because he finds "that the causal roles of natural kinds are more variegated and diverse than envisaged in Boyd's HPC theory" (2013, 122; see also Craver 2009); seeing natural kinds instead as "nodes in causal networks" allows us to unify a primarily epistemic approach to kinds with an appropriately metaphysical conception in virtue of which their epistemic utility is realized. P.D. Magnus, by contrast, proposes that a category is a natural kind for a given domain just in case that category both "allows the scientific enquiry into [that domain] to achieve inductive and explanatory success" and that no other category would do as well (Magnus 2012, 48).

The relativity to *domains* or *disciplines*[13] raises some thorny issues for the Realist. For it is less clear in this case that our scientific theories refer to a shared reality largely independent of our thought and talk. Ditto for accounts that make room for pluralism concerning the ways we divide up reality. Granted, such pluralists sometimes describe their views as "pluralistic realism" or "promiscuous realism" (Dupré 1983, 1993; Kitcher 1984), but one might doubt the coherence of this conjunction of ideas. How is it, one might ask that the world "can be divided up into kinds in

[13] Something that was also a feature of Boyd's approach: "the naturalness of a natural kind…is *discipline relative*" (1999, 148). See also Slater (2015) for an "adjectival approach" to natural kinds that attempts to unify cluster accounts like Boyd's with traditional essentialist accounts.

numerous different ways, and the results are all equally real" (Hull 1999, 25)? In what sense would such incompatible sets of divisions correspond to "the" structure of the objective world (cf. Waters 2017)? Scientific Realists of a more robustly metaphysical bent face the challenge here of connecting complex and sometimes pluralistic classificatory practices with an ontology that affords the mind-independence of the referents of the resulting categories. But even pluralists who place less emphasis on the metaphysical details of an account of natural kinds need an account of how their pluralism can avoid becoming an "anything goes" picture of scientific classification (Kitcher 1987).

These and other issues may convey the sense in which the subject of natural kinds is an important and fascinating nexus at which metaphysical and epistemological issues concerning science come together. What to say about these issues, how to approach them, and how to see them as connected to the debate about Scientific Realism remain in serious discussion.

Further reading. Metaphysically-oriented discussions of natural kinds may be found in the work of such Scientific Essentialists as Brian Ellis (*Scientific Essentialism*, Cambridge: Cambridge University Press, 2001) and Alexander Bird (*Nature's Metaphysics: Laws and Properties*, Oxford: Oxford University Press, 2007). A classic work on natural kinds and the unity of science that critically discusses the essentialism is John Dupré's *The Disorder of Things* (Cambridge: Harvard University Press, 1993); for more on the Causal Theory of Reference and the role of natural kinds in theory change, see Joseph LaPorte's *Natural Kinds and Conceptual Change* (Cambridge: Cambridge University Press, 2004). Other fine, recent book-length discussions of natural kinds that attend to scientific realism to different degrees are P.D. Magnus's *Scientific Enquiry and Natural Kinds: From Planets to Mallards* (London: Palgrave–Macmillan, 2012) and Muhammad Ali Khalidi's *Natural Categories and Human Kinds* (Cambridge: Cambridge University Press, 2013).

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