CHAPTER 19

NATURAL KINDS

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1 Preliminary Characterization

Consider the following scientific claims:

1. The Higgs boson can decay into two tau leptons.
2. There are 100 million black holes in the Milky Way galaxy.
3. Protons can transform into neutrons through electron capture.
4. Gold has a melting point of 1064° C.
5. Viruses multiply by attaching themselves to host cells.
6. The Eurasian wolf (*Canis lupus lupus*) is a predator and a carnivore.
7. Schizophrenics experience auditory hallucinations.

Some of the terms in these sentences designate individuals (e.g., *Milky Way*) or properties (e.g., *melting point of 1064° C*), but others refer to what philosophers have dubbed "kinds" or "natural kinds" (e.g., *proton, gold, Eurasian wolf*). Though scientists may not explicitly discuss natural kinds, they employ terms that denote neither individuals nor properties and would thereby seem committed to the existence of such things. To be sure, some of these terms can also be construed as referring to properties (e.g., the property of being a proton, atom of gold, or virus), but, in most of these cases, the term in question stands for a collection of properties that tend to be co-instantiated rather than a single property. For protons, these properties would be positive charge of 1.6×10^{-19} C, mass of 1.7×10^{-27} kilograms, and spin of ½. These three properties jointly specify what it is to be a member of the kind *proton*. Moreover, although all three properties are found together in all and only protons, they do not always co-occur in nature but are dissociable, since the charge of a proton is also carried by a pion (a π^+ meson), which has a different mass, and the spin of a proton is shared with an electron, which has a different charge. But when they are co-instantiated in the same individual, a number of other properties also tend to be instantiated. That would seem to be a central characteristic of natural kinds: they are associated with collections of properties that, when co-instantiated, result in the instantiation of yet other properties. Though a natural kind may occasionally be identifiable with a single property, that property must lead to the manifestation of a number of other properties for there to be a genuine distinction between kinds and properties. Many properties, even some of those properties associated with natural kinds, do not lead to the instantiation of a whole range of other properties, for instance the property of having a mass of 1.7×10^{-27} kilograms.

Natural kinds are said to have members, namely those individuals that possess the properties associated with the kind. All the kinds mentioned so far have as their members particular objects or entities (e.g., proton particle, atom of gold, virion), but there are also kinds of process or event, such as *radioactive decay, oxidization, volcanic eruption, supernova, species extinction, phosphorylation*, and *mitosis*. These are apparently also kinds, although their members are particular events or processes rather than objects or entities.

Now that we have a preliminary characterization of natural kinds, two philosophical questions can be raised about them (cf. Hawley and Bird 2011: 205; Khalidi 2013: 12):

1. Kindhood: *What* are kinds? Are kinds anything over and above their members? In other words, are they mere collections of individuals or are they universals or abstract entities in their own right?
2. Naturalness: *Which* kinds are natural? What makes a given kind natural? Is any assortment of properties a natural kind? Is any set of individuals, however arbitrary, equivalent to a natural kind?

These two questions are relatively independent, in the sense that the answer to one does not seem to preempt the answer to the other—unless one answers Question 2 by denying that there is any difference between natural and arbitrary categories, in which case it would be odd if not inconsistent to maintain that kinds are universals or abstract entities distinct from their members.

The first question takes us deep into the realm of metaphysics. The kindhood question is continuous with the traditional debate between realists and mominalists, between those philosophers who posit universals that correspond to properties and kinds and those who think that reality consists only of particulars and collections of such particulars. Universals can be transcendent (in the traditional Platonic conception), abstract entities that are not spatiotemporal, or immanent (in the view of some contemporary philosophers such as Armstrong [1989]), wholly present in each of their particular instances. The problems with both realism and nominalism are familiar and need not be rehearsed in detail here. Realists are committed to the existence of problematic entities with nonstandard attributes. If they are transcendent entities (like Plato's forms), then they exist outside of space-time and cannot be directly experienced. But if they are immanent (like Armstrong's universals), then they are capable of being wholly present in many different particulars at the same time. Both views posit entities that are very different from the familiar particulars that populate the universe. Moreover, realists about kinds face special problems not faced by realists about properties, since they must grapple with the question of whether kinds are universals over and above property universals or whether they are mere conjunctions of property universals, and each view comes with its difficulties. Meanwhile, nominalists encounter puzzles that arise from the fact that claims made about kinds cannot always be reduced to claims about their particular members (e.g., there are six kinds of quark, or there are more extinct than extant biological species). If such claims are not to be expunged from our discourse, they owe us an account of them.

The second question pertains more centrally to the philosophy of science. Here the issue is: Which categories correspond to natural kinds and which are just arbitrary; which categories capture something genuine about the universe and which are merely gerrymandered and unreflective of reality? Presumably, science has a say in the answer to this question, since it aims to isolate nonarbitrary categories that pertain to the very nature of the universe and to classify individuals into categories that reveal something about the universe itself. The paradigmatic natural kinds are often thought to be chemical elements, chemical compounds, and biological species. With the proliferation of scientific disciplines and subdisciplines, the candidates have multiplied, and this is perhaps what makes the problem more acute for contemporary philosophers. Do all these scientific categories correspond to natural kinds, and, if not, what would rule some of them out? And are there other natural kinds, apart from those countenanced by science?

Before delving into the question of naturalness in more detail, it will be useful to examine some historical and contemporary approaches to the topic of natural kinds. This is not just a matter of antiquarian interest, since "natural kind" is a philosophical term of art, and, hence, what its originators meant by it is a significant constraint on what it can be taken to mean. More important, these early discussions contain important insights and raise a number of issues that continue to figure prominently in debates about natural kinds.

2 Historical Antecedents

Discussion of natural kinds is implicit in the work of many philosophers of earlier eras, but the philosophical doctrine of "kinds" or "natural groups" appears to have been overtly articulated in the mid-nineteenth century first by William Whewell in *The Philosophy of the Inductive Sciences* (1840; 2nd ed. 1847) and then by John Stuart Mill in *A System of Logic* (1843; 8th ed. 1882). Neither Whewell nor Mill spoke of "natural kinds" but mostly just of "kinds." In addition to occasionally using the terminology of "kinds," Whewell also discusses "natural groups" and "natural classes," distinguishing them from artificial groups and classes. Meanwhile, Mill sometimes uses the expressions "real kind" and "true kind"; he also refers to "natural categories" and "natural groups."

Whewell holds that we classify things into kinds or classes based on similarity or resemblance. But resemblance among particulars can be analyzed further in terms of the possession of common properties, namely those properties that "enable us to assert true and general propositions" (1847: 486). Thus resemblance, and hence the classification of particulars into kinds, may only be ascertained after extensive scientific study of a domain, when we have been able to frame general propositions. Moreover, the general propositions that we assert about a kind or natural group need to agree with one another, leading to a "consilience" of properties. The true mark of a natural classification scheme is that it sorts individuals into groups that share properties that, although apparently disparate, are discovered to be consilient. Using mineralogy as his example, Whewell states that classifying minerals according to hardness, specific gravity, color, lustre, and other observable properties leads to the same classes as those obtained on the basis of chemical constitution, and this is a sign that we have a natural rather than an artificial system of classification. As he puts it: "each of these arrangements is true and natural, then, and then only, when it coincides with the other . . . such classifications have the evidence of truth in their agreement with one another" (1847: 541). The notion of "consilience of inductions" is an important feature of Whewell's philosophy of science, and it is central to his conception of natural groups and scientific classification schemes. He also sometimes refers to the idea of the coincidence among different sets of properties by the term "affinity". Significantly, Whewell denies that all natural groups or classes have definitions; instead, they are often organized around a type or specimen. But even though natural groups may not always be definable, he does not think that makes them arbitrary; natural classes are given "not by a boundary line without, but by a central point within" (1847: 494). Another innovation of Whewell's is that he thinks that natural groups may sometimes not be sharply divided and that there may be individuals intermediate between two natural groups, or groups intermediate between superordinate groups (1847: 495).

Mill agrees with the identification of kinds with a number of co-instantiated properties or attributes. This means that a multitude of general assertions can be made about them and they can serve as the basis for inductive inference, since we infer from the presence of some of those properties the presence of others. So far, Mill's view concurs broadly with Whewell's, but he qualifies this characterization in at least two crucial ways. First, he thinks that the properties associated with kinds must be "inexhaustible" or "indefinite" in number, and second, he holds that they must not follow or be deducible from one another by an "ascertainable law" (1882: I vii 4). On the first count, some of Mill's critics have wondered why the number of properties involved must be indefinite in number. After all, if a number of different properties are jointly instantiated in natural kinds and they enable us to make inductive inferences and project to new instances, it does not seem necessary to require that they be inexhaustible. The second claim is also controversial, since, as critics such as C. S. Peirce (1901) observed, the very point of scientific inquiry is presumably to discover the laws that connect the properties associated with kinds. Sometimes Mill suggests that the properties of kinds are linked as a mere matter of coexistence or by "uniformities of coexistence"—in other words, a kind of ultimate brute fact (1882: III xxii 2). However, at other times he seems to allow the properties associated with kinds to be causally linked: "The properties, therefore, according to which objects are classified, should, if possible, be those which are causes of many other properties: or at any rate, which are sure marks of them" (1882: IV vii 2; cf. 1882: III xxii 2). Moreover, he suggests that uniformities of coexistence, unlike causal uniformities ("uniformities of succession"), only account for the co-instantiation of the ultimate properties in nature, "those properties which are the causes of all phenomena, but are not themselves caused by any phenomenon" (1882: III xxii 2). This would suggest that coexistence obtains for the properties of the most fundamental kinds, whereas causality might obtain among the properties of other kinds.

A further complication in Mill's view is that at times he identifies kinds with natural groups or groups that feature in scientific classification schemes, but at other times he states that real kinds are a subset of such groups. After equating kinds with natural groups, he goes on to say that although all plant species are real kinds, very few of the higher taxa, such as genera and families, can be said to be kinds (1882: IV vii 4). What would disqualify such classes from corresponding to kinds? One additional condition that he places on kinds, as opposed to groups in natural classification schemes, is that there be an "impassable barrier" between them and that they be entirely distinct from one another (1882: IV vii 4). In contrast with Whewell, Mill thinks that there cannot be intermediate members between real kinds; as he puts it, they must be separated by a "chasm" rather than a "ditch" (1882: I vii 4). In pre-Darwinian biology, species were commonly thought to satisfy this condition but not higher taxa. Mill also disagreed with Whewell about types, denying that natural groups could be delimited by typical members and considering definitions to be important to the delimitation of natural groups (1882: IV vii 4). Finally, Mill affirms that different sciences may classify the same individuals in different ways, since these classifications may serve different purposes; for example a geologist categorizes fossils differently from a zoologist (1882: IV vii 2).

The logician John Venn built on the insights of Whewell and Mill, emphasizing the importance of natural groups for probabilistic inference and statistical generalization.[1] For Venn, who was primarily interested in probability and induction, natural kinds or natural groups are the main grounds of statistical inference. He writes in the *Logic of Chance* (1866; 3rd ed. 1888): "Such regularity as we trace in nature is owing, much more than is often suspected, to the arrangement of things in natural kinds, each of them containing a large number of individuals" (1888: III, sect. 3). It is these regularities that enable us to project from one instance of a kind to another, or to make general statements about them. Venn was particularly interested in cases in which causal links between properties were not strict and where accurate predictions could not be made about single cases but only about large numbers of them. When the properties associated with natural kinds are not linked to them invariably but only with a certain frequency, "there is a "limit" to which the averages of increasing numbers of individuals tend to approach" (1888: XVIII sect 16).

[1] Hacking (1991: 110) credits the first usage of the expression "natural kind" to Venn. But in using that term, Venn seems to have thought he was following Mill's own usage. There is a possibility that Venn misremembered Mill's exact expression and inserted the modifier "natural" inadvertently.

In a later work, *The Principles of Empirical or Inductive Logic* (1889; 2nd ed. 1907), Venn distinguished "natural substances" from "natural kinds," the former being chemical elements and compounds and the latter biological species. He also held that many conventional actions or institutional phenomena share the features of natural kinds. In all these cases, the particulars falling under the kinds possess a number of common attributes, although "attributes are not things which can be counted like apples on a tree" (1907: 333). Still, we choose the attributes upon which to base our classifications in such a way that one attribute will point to a number of others as well. For example, if we classify plants not on the basis of color but on the structure of the seed, we will find that a number of other attributes will be associated with that attribute (Venn 1907: 335). Venn also seems to endorse Mill's requirement that natural kinds ought to be separated from one another by a sharp divide (335). However, he notes that these two requirements may not always coincide, because there could be classifications that are based on maximizing the number of coincident properties, which, however, do not lead to clean breaks between classes (336). Like Mill, Venn subscribes to the interest-relativity of classification schemes, averring that each will serve a specific purpose (562).

Peirce's views on natural kinds emerged initially in opposition to Mill's. As already mentioned, he objects strenuously to Mill's apparent contention that the properties of natural kinds should not be linked by law. Instead, he claims that scientists aim precisely at accounting for the connections between the various properties associated with natural kinds. He also proposes an alternative definition of a "real kind": "Any class which, in addition to its defining character, has another that is of permanent interest and is common and peculiar to its members, is destined to be conserved in that ultimate conception of the universe at which we aim, and is accordingly to be called 'real.' "(1901). There are two features of this definition that are worth underlining. First, Peirce is rather minimalist in allowing a kind to have just two properties pertaining to it, presumably properties that are logically independent though linked by scientific law. Second, he builds into his definition a conception of the end of inquiry by suggesting that we cannot definitively rule on kinds until we have an ultimate scientific theory. Elsewhere, Peirce (1902/1932) linked natural kinds to final causation, characterizing a "real" or "natural class" as "a class of which all the members owe their existence as members of the class to a common final cause." Like Whewell but unlike Mill, Peirce (1902/1932) also denies that there are always sharp divisions between natural classes and holds that not all natural classes are definable, maintaining that there may be no essential properties that are both necessary and sufficient for membership in a natural class.

After these seminal discussions of natural kinds from the mid-nineteenth century into the first decade of the twentieth, the topic was seldom discussed until the 1970s, with three notable exceptions: the work of C. D. Broad, Bertrand Russell, and W. V. Quine. One can discern a definite trajectory in the views of these three philosophers, as they represent increasing disillusionment with the notion of natural kinds and growing skepticism regarding their utility for science.

Broad invokes natural kinds in discussing induction by enumeration, saying that such inductions are plausible when it comes to natural kinds (e.g., crows, swans, pieces of silver) but not when it comes to non-natural kinds (e.g., billiard balls, counters in a bag). But Broad's main innovation is the introduction of a striking and influential image for conceiving of natural kinds (although it is not clear whether it was proposed independently by others). Imagine an *n*-dimensional state space of *n* properties (e.g., color, temperature, hardness), each of which can take on various values, and plot each individual in the universe as a point in this space depending on the values that it has for each property. If we carry out this exercise, what we find is "a 'bunching together' of instances in the neighborhood of certain sorts of states," rather than a uniform distribution (Broad 1920: 25). In other words, some combinations of properties are very common in the universe whereas others are rare or nonexistent. To make the illustration more vivid, Broad asks us to imagine a fluid spread out in this space such that its density at any point represents the number of individuals with that combination of properties:

> We should find a number of blobs in the space surrounding certain points. These blobs would be very dark near their centres and would shade off very quickly in all directions as we moved away from these centres. In the regions between the blobs there would be practically no dots at all, and such as there were would be extremely faint." (1920: 26)

As well as serving as a compelling representation of natural kinds, this analogy contains a couple of important claims, first that members of natural kinds need not have exactly identical properties, just similar properties whose values cluster around a "type," and second that even though intermediate instances between two or more natural kinds may be very rare, they are not nonexistent. Both points were mentioned in connection with Whewell's views on kinds and were denied by Mill. Moreover, Broad stresses that the existence of "blobs" is a contingent feature of the universe, and the fact that not all combinations of properties are allowable is due to the operation of causal laws. In the end, he concludes that the notion of natural kinds is intertwined with that of causation (1920: 44). In making inductive inferences, we simply assume that natural kinds exist, but this assumption is not capable of proof, although it forms the basis of our scientific inquiries (1920: 42).

Russell begins by characterizing natural kinds as "a class of objects all of which possess a number of properties that are not known to be logically interconnected" (1948: 278). He also states that there are certain laws that make some combinations of properties more stable than others and affirms that these "functional laws of correlation" are "probably more fundamental than natural kinds" (390). Moreover, in physics, the properties associated with atomic elements are no longer thought to coexist "for no known reason" but are rather now held to be due to "differences of structure." This means that the only natural kinds whose properties are correlated for no known reason (according to the physics of his day) are electrons, positrons, neutrons, and protons, although Russell states that eventually these "may be reduced to differences of structure" (1948: 390). In short, Russell's treatment seems to contain the same tension found in Mill, in considering natural kinds to be associated with properties that are correlated due to laws of coexistence while also allowing them to be correlated due to causal laws. But in contrast to most of the philosophical tradition, Russell seems to think that natural kinds will be superseded as science comes to discover the laws that account for the coincidence of their properties and that natural kinds will be a "temporary phase" on the road to the discovery of scientific laws that relate properties directly to one another.

On this last point, Quine would seem to agree with Russell, although he does not cite him in this context. In fact, Quine has two main objections to the utility of the notion of natural kinds in modern science. First, he thinks that the notion is mired in the obscure idea of similarity and cannot therefore serve as a sound basis for scientific theorizing. Indeed, matters are even worse since one cannot even define "kind" precisely in terms of similarity due to various logical complications. Second, Quine thinks that in certain domains, similarity can be bypassed in favor of the matching of components or the coincidence of properties; in chemistry, for instance, "Molecules will be said to match if they contain atoms of the same elements in the same topological combinations" (1969: 135). But if one understands similarity in this way, then one has effectively traded a generic notion of similarity for one that applies specifically to this case and relies ultimately on identity of molecules. It is not clear from Quine's analysis why such exact measures of property coincidence would not lead to retaining natural kinds rather than rendering them extinct. Perhaps his point is that there is no need to posit kinds once one has laws that directly link properties, or perhaps he thinks that the similarity standards operative in different branches of science do not have anything interesting in common, so there is no generic notion of natural kind, just the kinds posited in each specific science.

Having examined the tradition from Whewell to Quine, several themes emerge in discussions of natural kinds, some of which represent points of consensus while others are matters of contention. There seems to be broad agreement that natural kinds collect together particulars that are similar in certain respects, where similarity may be understood in terms of sharing properties as posited by an established scientific theory (rather than superficial similarity). This means that categories corresponding to natural kinds support inductive inference and enable us to make true generalizations. Moreover, that is because natural kinds are associated with collections of properties that are not logically linked but are correlated either as a matter of brute coexistence or as a matter of causality or both. There is some disagreement as to whether these correlated properties should be indefinite in number (Mill), or just a large number (Whewell, Venn, Broad, Russell), or even as few as two (Peirce). There is no consensus on the definability of natural kinds, with some arguing that they are definable (Mill) and others that they are not always so (Whewell, Venn, Peirce, Broad). There is also controversy as to whether natural kinds must be separated from one another by a chasm with no intermediate members (Mill, Venn) or whether they can shade off into one another without discrete breaks (Whewell, Broad). Finally, most of these authors are pluralists and allow the possibility that classification by natural kinds may be discipline-relative, with different scientific disciplines sometimes classifying the same individuals differently.[2]

[2] This retelling of the history of the natural kind concept can be contrasted with the ones given in Hacking (1991, 2007) and Magnus (2013), where more discontinuity is found in the tradition of philosophical discussion of natural kinds.

3 Contemporary Approaches

The two most influential approaches to natural kinds in the recent philosophy of science are essentialism and the homeostatic property cluster (HPC) theory.

3.1 Essentialism

Essentialism is an ancient doctrine in philosophy, but it has been revived in contemporary discussions of natural kinds due to considerations deriving from the usage of certain terms in natural language. In discussions of meaning and reference, Kripke (1971/1980) and Putnam (1975) both noted parallels between proper names (e.g., "Aristotle") and natural kind terms (e.g., "gold," "water," "tiger"). Their basic observation was that the two types of terms could be used to refer successfully by a speaker even though the speaker was partly ignorant of or misinformed about the properties associated with the referent.[3] Reference in these cases is not to whatever possesses the properties associated by the speaker with the referent but to the referent's real essence. In the case of natural kinds, successful reference by a speaker depends not on possessing a description that uniquely identifies the natural kind but (at least in part) on causal contact with an exemplar of that kind (contact that may be mediated by other speakers). For example, the term "gold" can be used to refer successfully even though a speaker might be mistaken about the properties of gold, or even if something of a different kind has those same properties (e.g., pyrites). Furthermore, a natural kind term like "gold" is a "rigid designator" in the sense that it would refer to the same kind of thing in every possible world in which that substance exists. Hence, what the term "gold" refers to, in the actual world or in other possible worlds, is any exemplar that has the real essence of gold, the substance that was initially dubbed by speakers when the term "gold" was introduced.

This account of reference presupposes that there is an essence associated with each natural kind to which our terms ultimately point, even though we may be unaware of that essence and it may take an undetermined amount of time for us to discover it. If by "essence" is meant something loosely like the true nature of the thing, then that presupposition might not be a very controversial one. But numerous philosophers who built on the work of Kripke and Putnam have come to associate essences with various more substantive features (and some of these features are at least implicit in the work of Kripke and Putnam themselves and may be required by their theory of reference). Thus

[3] However, Putnam's extension of these claims from proper names to natural kind terms was somewhat more cautious. He writes, for example: "it is instructive to observe that nouns like 'tiger' or 'water' are very different from proper names. One can use the proper name 'Sanders' correctly without knowing anything about the referent except that he is called 'Sanders'—and even that may not be correct" (1975: 166).

the claim that natural kinds have essences has come to encompass a number of theses, including some or all of the following:

1. Necessary and sufficient properties: An essence consists of a set of properties, possession of which is singly necessary and jointly sufficient for membership in a natural kind.
2. Modally necessary properties: An essence consists of a set of properties that are (a) necessarily associated with the natural kind (i.e., associated with it in all possible worlds) and/or such that (b) members of the kind possess them necessarily (i.e., possess them in every possible world).[4]
3. Intrinsic properties: An essence consists of a set of properties that are intrinsic to members of the kind (rather than relational, extrinsic, functional, etiological, and so on).
4. Microstructural properties: An essence consists of a set of properties, all of which are microstructural in nature (i.e., pertain to the microconstituents of the kind and their arrangement in a certain configuration, such as the structural formula of a chemical compound).

Sometimes additional claims are made regarding essences:

5. Essential properties issue in sharp boundaries between natural kinds.
6. Essential properties result in a hierarchy of natural kinds that cannot crosscut one another.
7. There is a bedrock of most fundamental essences that result in a basic level of natural kinds (infima species).

Although essentialism continues to have many adherents and may indeed be the default position among contemporary philosophers, there is increasing disenchantment with it, especially among philosophers of science. One main source of dissatisfaction relates to a perceived misalignment between the claims of essentialism and the results of science. Essentialism is controversial across a wide swathe of sciences, particularly the "special sciences" that pertain to various macro-domains (e.g., fluid mechanics, stellar astronomy, biochemistry, geology), in which many kinds are functionally characterized rather than intrinsically and in terms of macro-properties rather than micro-structure. Moreover, it has become increasingly clear that the key essentialist features are not found even in many of the paradigmatic instances of natural kinds. Of course, it is always open in principle to save the essentialist thesis in question by ruling that the alleged instances are not in fact natural kinds. But if this occurs for many if not most of the paradigmatic natural kinds, it may be more reasonable to reject the thesis and preserve the natural kind.

It is not difficult to see that the essentialist theses are violated by a range of categories that are strong candidates for natural kinds, such as the atoms of chemical elements.

[4] Some essentialists would say *nomologically* possible worlds, but others think that the laws of nature are inherent in the essences, so they would say *metaphysically* possible worlds (Ellis 2001).

Consider thesis 2b, the claim of modal necessity. Since elemental atoms can decay into atoms of other elements, they can become atoms of other kinds (e.g., an atom of uranium-234 decays into an atom of thorium-230). This implies that they do not always belong to the same kind in the actual world. Hence one cannot maintain that atoms of chemical elements belong to those elemental kinds necessarily or in all possible worlds. Although they could still be said to satisfy 2a, since the properties associated with each kind of chemical element can be said to be associated with that kind in every possible world, this thesis seems to be satisfied trivially by categories that do not correspond to natural kinds. For example, the category of things that have a *mass of less than one kilogram* is associated with that very property in every possible world, yet no one would claim that it corresponds to a natural kind. Similar problems arise when it comes to biological species. Consider theses 1 and 3, the claims that essential properties are necessary and sufficient for membership in a kind and intrinsic to the kind, respectively. There is no intrinsic set of properties common to all and only members of a particular biological species (e.g., certain strands of DNA or a collection of genes, much less phenotypic features), so these claims are not jointly true of species. Moreover, if the essence of a biological species is taken to be historical rather than intrinsic (as many philosophers of biology would claim), then it would satisfy 1 but not 3 (or 4). In response to such problems, some essentialist philosophers have ruled that species are not natural kinds (Wilkerson 1993; Ellis 2001), while others have concluded that species have extrinsic historical essences, thereby giving up on theses 3 and 4 (Griffiths 1999; Okasha 2002), and yet others have challenged the consensus of biologists and philosophers of biology, maintaining that species do have intrinsic essences (Devitt 2008). Meanwhile, Laporte (2004) argues that 2b is also violated for biological species. In sum, it is clear that even some of the paradigmatic natural kinds fail to satisfy each of 1 through 4, let alone 5 through 7.

In addition to these doubts about specific essentialist theses, questions have also been raised about the cogency of deriving essentialist metaphysical conclusions from observations concerning the use of terms in natural language. If the use of certain general terms presupposes that kinds have essences, this presupposition may just reflect a human cognitive bias that is displayed in features of natural language (Leslie 2013). In response, it might be said that the presuppositions that underwrite our linguistic usage are themselves firm metaphysical intuitions (e.g., about what would be the same substance in other possible worlds). But not only are these intuitions largely unjustified postulates, they are not universally shared, as many early critics of Kripke and Putnam pointed out (e.g., Mellor 1977, Dupré 1981).

3.2 Homeostatic Property Clusters

A different account of natural kinds has been proposed in a number of papers by Richard Boyd (1989, 1991, 1999a, 1999b), whose theory adheres more closely to the details of at least some scientific categories. Boyd begins from the insight that many kinds in the special sciences correspond to property clusters. In describing them as "clusters," he is arguing for a frequent co-occurrence among the properties while allowing for a certain looseness of association among them. This constitutes a departure from essentialism as ordinarily understood, and the break with essentialism is confirmed by Boyd when he writes: "The natural kinds that have unchanging definitions in terms of intrinsic necessary and sufficient conditions . . . are an unrepresentative minority of natural kinds (perhaps even a minority of zero)" (1999a: 169). Instead of a set of properties that are singly necessary and jointly sufficient for membership in the kind, Boyd holds that members of a kind may share a largely overlapping set of properties. That is because many natural kinds consist of properties loosely maintained in a state of equilibrium or homeostasis. This is achieved by means of an underlying mechanism that ensures that many of these properties are instantiated together, although it may also be that "the presence of some of the [properties] favors the others" (Boyd 1989: 16). Either way, we denote this loose collection or cluster of properties by some kind term, which picks out either all or most of the properties in the cluster and possibly some of the underlying mechanisms as well. Although Boyd (1999a: 141) sometimes notes that the HPC theory can be considered the essence of a natural kind and allows that natural kinds have "definitions" provided by the cluster, this is clearly not a version of essentialism in the ordinary sense. Some philosophers who have endorsed the HPC account of natural kinds think that it is compatible with essentialism (Griffiths 1999), but most have regarded it as an alternative to essentialist accounts.

Boyd emphasizes that the fact that properties cluster loosely, rather than by way of necessary and sufficient conditions, is a contingent fact about the world rather than a reflection of our ignorance. It arises because in the special sciences, there are few if any exceptionless laws to be found. Instead, there are "causally sustained regularities" that apply to natural kinds and specify their properties in such a way as to allow for exceptions and instances in which properties are imperfectly correlated (Boyd 1999a: 151–152, 1999b: 72). The fact that such generalizations are not exceptionless or eternal by no means suggests that they are merely accidental, since they are sustained by underlying causal structures (Boyd 1999a: 152). Although Boyd does not appear to say this in so many words, clustering occurs because many causal connections in the universe are not strict, and this is due to the fact that some causal processes can interfere with other causal processes, leading to the imperfect co-instantiation of groups of properties. That is presumably why we find loose clusters of causal properties rather than exactly the same set of properties in every individual member of a kind.

An important aspect of Boyd's account is what he calls the "accommodation thesis," namely the claim that we devise our categories in such a way as to accommodate the causal structure of the world. The fact that some inductive generalizations are true and the terms that feature in those generalizations are projectible (Goodman 1954/1979) is a reflection of this causal structure. Boyd sums up his conception of accommodation as follows:

> We are able to identify true generalizations in science and in everyday life because we are able to accommodate our inductive practices to the causal factors that sustain them. In order to do this—to frame such projectable generalizations at all—we require a vocabulary . . . which is itself accommodated to relevant causal structures. (1999a: 148)

Boyd never meant his account to apply across the board to all natural kinds but at best to a range of natural kinds in the special sciences, which as he says "study complex structurally or functionally characterized phenomena" (1989: 16). Although he often mentions biological examples like species and higher taxa, he also refers in passing to natural kinds in geology, meteorology, psychology, and the social sciences. Like many philosophers in the tradition of theorizing about natural kinds, Boyd affirms "disciplinary or sub-disciplinary pluralism about natural kinds" (1999b: 92), such that natural kinds in one discipline may not be such in another. But he also makes the point that some natural kinds facilitate inductions and feature in explanations "beyond the domain of a single scientific discipline" (Boyd 1999b: 81).

Despite the fact that Boyd's account seems to accord with a range of natural kinds in the special sciences, particularly the biological sciences, some philosophers have found it wanting precisely when it comes to capturing the nature of these kinds. It has been argued that Boyd's focus on interbreeding as the homeostatic mechanism that preserves the stability of biological species does not do justice to the historical nature of species. Moreover, given polymorphisms within biological species, there is no cluster of properties common to all members of a species that are kept in equilibrium (Ereshefsky and Matthen 2005). Other philosophers have defended the HPC account by allowing a number of different mechanisms to account for the stability of species (Wilson, Barker, and Brigandt 2009). However, even if Boyd's account aptly characterizes a range of natural kinds in the special sciences, where homeostatic mechanisms are plentiful and many systems have elaborate feedback mechanisms that maintain them in a state of equilibrium, it may not account for all such kinds (let alone nonspecial science kinds such as those of elementary particle physics). The HPC account certainly represents an advance over essentialist views in its fidelity to scientific practice, but it may not go far enough in the direction of naturalism.

4 A Naturalist Alternative

What would a naturalist approach to natural kinds look like? A naturalist approach is one that takes its cue from science rather than specifying certain conditions that natural kinds should meet on a priori grounds or on the basis of conceptual analysis. To determine which categories correspond to natural kinds, we should ascertain which categories matter to science. Does this mean that our default assumption should be that all categories that occur in our current best scientific theories correspond to natural kinds? There are two caveats here. The first is that scientific theories are corrigible, so that our current best theories might be revised and at least some of their categories revoked or abandoned. A definitive judgment concerning the identity of natural kinds can only be made when and if the categories of science are finalized (Khalidi 2013). The second caveat is that not every category invoked in scientific inquiry, much less every one mentioned in a scientific journal article, plays an indispensable epistemic role in the relevant science (Magnus 2012). Some categories may be redundant, or adopted for nonscientific purposes, or incidental to the actual practice of scientific inquiry, or holdovers from discredited scientific theories.

On this way of characterizing naturalism, it is not a position universally shared by contemporary philosophers. Some philosophers would insist, rather, that philosophy ought to specify the conditions that natural kinds should meet, and then science will tell us which entities in the world satisfy those conditions.[5] The first step presupposes that philosophy has access to conceptual or a priori truths independently of the deliverances of science. That is an assumption that many contemporary naturalists would dispute. But does naturalism then imply that philosophy simply registers what science has to say and that it has no original contribution to make on this and other matters? No, because, as already suggested, a critical philosophical stance can help to determine whether some scientific categories are redundant, dispensable, inconsistent, or incoherent.

A number of contemporary philosophers have adopted such an approach, identifying natural kinds with categories that play an epistemic or investigative role in science, sometimes referring to them as "epistemic kinds" or "investigative kinds" (Kornblith 1993; Brigandt 2003; Griffiths 2004; Craver 2009; Weiskopf 2011; Magnus 2012; Slater 2014; Franklin-Hall 2015). One common denominator among most (but not all; see Ereshefsky and Reydon 2014) recent approaches to natural kinds is the claim that categories corresponding to natural kinds are projectible, play a privileged role in induction, and feature in explanatory arguments. In fact, this approach is already found in Boyd's account of natural kinds and is implicit in his "accommodation thesis." As Boyd puts it: "It is a truism that the philosophical theory of *natural* kinds is about how classificatory schemes come to contribute to the epistemic reliability of inductive and explanatory practices" (1999a: 146; emphasis in original). Thus certain categories play a role in scientific discovery, explanation, and prediction and figure in successful inductive inferences. A number of nontrivial generalizations can be made using such categories, and any new member that is classified under such a category is likely to have all or many of the other associated features. Moreover, there are many such features associated with the kind, not just a few, and we tend to discover more as time goes by (although not necessarily an indefinite number, as Mill held).

Rather than rest with a purely epistemic understanding of natural kinds, one can ask, in line with Boyd's accommodation thesis: What are the ontological underpinnings of the epistemic role of natural kind categories? According to the tradition beginning with Whewell and Mill, natural kinds are associated with a cluster of properties that when co-instantiated lead to the instantiation of a multitude of other properties. If kinds are just clusters of properties, the question arises: Why do properties cluster? If we think of some of the most fundamental constituents of the universe, such as quarks or leptons, there does not seem to be an answer to the question as to why they have the basic properties that they do. At least in the current state of scientific theorizing, there is no widely

[5] See Papineau (2009) for a characterization of the contrast between the naturalist approach and the alternative.

accepted explanation of their having just those combinations of mass, charge, spin, and other quantum numbers. An explanation may yet be found, but it may also be that for the most fundamental kinds (whatever they may turn out to be) the co-occurrence of their "core" properties is just a matter of brute coexistence. However, when it comes to other natural kinds, even the chemical elements, there is a causal account of the clustering of properties. An atom of carbon-12, for example, has six protons, six neutrons (each of which consist of three quarks), and (in a nonionized state) six electrons, and we have scientific theories that tell us why those particular combinations of particles are stable, namely the theories of strong forces and electroweak forces. Hence there is a causal account of the co-instantiation of the properties of carbon atoms. Moreover, many of the macro-level properties of large assemblages of carbon atoms can also be accounted for with reference to the micro-level properties of carbon atoms. Here too there are causal theories that explain why these micro-properties, when aggregated in certain ways and in certain contexts, will yield just those macro-properties. For a different isotope of carbon, carbon-14, the different macro-properties (e.g., half-life) will be accounted for with reference to slightly different micro-properties. Once the "core" properties of natural kinds cluster together, the "derivative" properties follow as a matter of causality. Even with regard to the properties of elementary particles, their quantum numbers may be co-instantiated by way of mere coexistence, but their derivative properties are causally linked to those core properties. For instance, the fact that electrons curve in the opposite direction as positrons in an electromagnetic field, or that they leave a visible track in a cloud chamber, follows causally from the more basic properties of electrons.

So far we have canvassed two reasons for the co-instantiation of the core properties of natural kinds—brute coexistence and causal relations—just as Mill seems to have held. Another reason that is sometimes given for the clustering of properties in nature as well as in the social world is the presence of a copying mechanism. Ruth Millikan (1999, 2005) distinguishes "eternal kinds" from "copied kinds" (or "historical kinds") on the grounds that the latter share certain properties not as a result of natural law but rather as a consequence of a copying process that ensures that many of the same properties are instantiated in individual members of those kinds. As she puts it, each member of the kind "exhibits the properties of the kind because other members of that same historical kind exhibit them" (1999: 54). This is supposed to obtain for biological kinds such as species (e.g., *tiger*), as well as for many social kinds (e.g., *doctor*) and artifactual kinds (e.g., *screwdriver*). Moreover, members of such kinds may not all share exactly the same set of properties and may not be separated from members of other kinds by sharp boundaries. They belong to the same kind because a copying process has produced the kind members from the same models, they have been produced in response to the same environment, and some function is served by members of the kind (Millikan 2005: 307–308). However, although Millikan makes much of this division between two kinds of kinds, causal relations are also central to copied kinds, since the copying process that gives rise to all members of the kind would not copy them had they not performed a certain function in a particular environment. Moreover, there would appear to be some kinds that combine features of both natural and copied kinds, for example DNA molecules.

Millikan also refers to copied kinds as "historical kinds," but there is a distinction to be made between copied kinds and etiological kinds, which are individuated solely or largely in terms of a shared causal history. Members of some kinds from a variety of sciences are grouped together because of the fact that they are the result of the same or exactly similar causal process. This does not necessarily entail being copied in response to the same environment or serving the same function. Consider the cosmological kind *cosmic microwave background radiation*, which includes all radiation left over from the Big Bang. Collections of photons belonging to this kind are intrinsically indistinguishable from others that have the same frequency yet are distinguished from them because of their common origin. Similarly, members of a geological kind like *sedimentary rock* are grouped together and distinguished from other rocks on the basis of the process that gave rise to them. Some of them may share causal properties as well, but they are primarily individuated on the basis of the causal process that produced them. Etiological kinds can therefore be distinguished from other kinds on the grounds that they possess a shared causal history, although they do not necessarily share synchronic causal properties (at any rate, not ones that distinguish them from some nonmembers). They are also causally individuated, but with reference to diachronic rather than synchronic properties. Some philosophers may consider etiological kinds not to be natural kinds, but many categories drawn from a range of sciences are at least partly etiological, including biological species. If they are considered natural kinds, then they are also causally individuated, although on the basis of diachronic rather than synchronic causality. Hence, apart from those fundamental kinds whose "core" properties cluster as a matter of coexistence, it appears as though the common ontological ground for natural kinds is causal.

5 Remaining Questions and Future Directions

A contrast is often drawn between interest-relative classification and objective or human-independent classification. However, if the previously discussed considerations are correct, this contrast is overblown. It is true that some interests are involved in constructing our categories and delimiting their boundaries, but if the interests are epistemic—that is, they aim to acquire knowledge of the world by locating categories that are projectible, support inductive generalizations, have explanatory value, and so on—then they ought to enable us to identify genuine features of the world. As long as the interests guiding our taxonomic schemes are epistemic, they should point us in the direction of real distinctions in nature. Nevertheless, naturalism is compatible with the claim that there may be a variety of genuinely epistemic interests, which may pertain to different scientific disciplines or subdisciplines. This may result in different taxonomic schemes that classify the same individuals in a crosscutting manner. Two individuals, i_1

and i_2, may be classified in some taxonomic category K_1 by one branch of science, while i_2 may be classified with some other individual i_3 in category K_2 by another branch of science, where neither category K_1 nor K_2 includes the other (Khalidi 1998). Although crosscutting taxonomies reflect different interests, they do not necessarily undermine realism; provided they are epistemic interests they will presumably uncover different aspects of the causal structure of the universe. But one may still harbor doubts as to whether even our most considered epistemic categories generally cleave to the joints of nature. These doubts may loom larger if we allow that some of our categories are delimited for reasons of human convenience, ease of measurement, relevance to human well-being, and other idiosyncratic considerations. Hence it may be argued that even at the idealized end of inquiry, some details concerning the boundaries of our categories or their specific features may be determined in part by our human predilections. It is an open question as to whether and to what extent such considerations play a role in demarcating our categories and hence to what extent these categories correspond to nature's own divisions.

The naturalist conception of natural kinds is an avowedly pluralist one, countenancing a more diverse set of natural kinds than some traditional philosophers might have allowed. But there is a more radical variety of pluralism about natural kinds that needs to be mentioned, namely pluralism about the notion of natural kind itself. Despite the unitary causally based account of natural kinds offered in the previous section, it may be possible to maintain that there is no single notion of natural kind that is applicable to all the diverse branches of science and across all scientific domains. Just as some philosophers have argued for a pluralist conception of causality, with several types of causal relation, each playing a central role in different areas of science, others have held that diverse factors ground natural kinds in different domains (Dupré 2002). This position was already prefigured in the discussion of Quine's views on natural kinds, and it remains to be seen whether all the natural kinds identified by science can be made to fit a single overarching (causal) template.

The naturalist characterization of natural kinds is in principle amenable to the existence of natural kinds in the social sciences, and this accords with the thinking of at least some nineteenth-century philosophers (Mill, Venn, and Peirce, all countenance social kinds). But there are some obstacles to assimilating social kinds to natural kinds. Some philosophers claim that social kinds are ontologically subjective, depending for their very existence on human mental attitudes (Searle 1995). Others argue that they are different from natural kinds because they are interactive and can change in response to our attitudes toward them, in what Hacking (1999) has dubbed the "looping effect" of social or human kinds. Perhaps most important, some philosophers hold that the difference between natural kinds and social kinds is that the latter are fundamentally evaluative or normative in nature (Griffiths 2004). These are all significant challenges to the incorporation of social kinds into natural kinds, and there is more work to be done to ascertain whether these features obtain for all social kinds and whether they preclude their being natural kinds. Meanwhile, the term "natural kind" should not be taken to preempt this issue, with its implied contrast between the natural and the social. Since it should be an open question as to whether social kinds can be natural kinds, it might have been better to adopt the term "real kind" instead of "natural kind." This would also have helped dispense with the problematic assumption that natural kinds cannot be artificially produced, since it is clear that many human-made kinds are good candidates for natural kinds, for example synthetic chemical compounds, artificially selected organisms, and genetically engineered organisms.

If one thinks of natural kinds as corresponding to clusters of causal properties, the possibility arises that there may be more such clusters than human beings are able to observe or apprehend. This means that although our most established scientific categories will indeed correspond to natural kinds, there may be a multitude of other natural kinds that we have not succeeded in capturing. The naturalist account of natural kinds is realist, but it allows that there may be more kinds of things in the universe than are dreamt of in a completed science. It may be that, given human frailties and limitations, the kinds that we identify are a small fraction of those that exist in the universe. This consequence may be thought to undermine realism, since it leads to too many natural kinds, only some of which we will actually identify. But it is not clear why allowing an abundance of natural kinds and admitting our inability to identify them all would impugn their reality. An alternative that is sometimes suggested consists in identifying the natural kinds with the most fundamental kinds in nature: quarks, leptons, and bosons (at least according to our current theories). There are a couple of problems with this view. First, it is possible that there is no fundamental level in nature but that the universe consists of strata of evermore fundamental entities (Schaffer 2003). Second, it leaves many of the interesting questions that exercise philosophers as well as working scientists unaddressed, namely questions about which categories and systems of classification we should adopt beyond the most fundamental level. The question of natural kinds is not just of philosophical interest; it occurs at least implicitly in many scientific controversies. Questions often arise over the validity of certain categories or their legitimacy, such as *Asperger syndrome, race*, or *social class*. These questions appear not just in psychiatry and the social sciences but also in the natural sciences. Consider: Is *dark matter* a natural kind? That is, is there a uniform kind of thing that is a (hitherto undiscovered) kind of matter and is characterized by a number of properties that give rise to a multitude of others? Or are there perhaps two or a few such kinds? Or is "dark matter" just a catchall term for whatever it is that accounts for a discrepancy in our calculations or has certain gravitational effects, without having a common set of properties? Presumably, these questions are at the heart of contemporary physical and cosmological inquiries. If we answer the last question in the affirmative, then one way of putting our conclusion would be: *dark matter* is not a natural kind.

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