THE METAPHYSICS OF NATURAL KINDS

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Abstract

Rev.8.2—Thursday 12th August, 2010, 11:20 This paper explores the metaphysics of natural kinds. I consider a range of increasingly ontologically committed views concerning natural kinds and the possible arguments for them. I then ask how these relate to natural kind essentialism, arguing that essentialism requires commitment to kinds as entities. I conclude by examining the homeostatic property cluster view of kinds in the light of the general understanding of kinds developed.

1 Introduction

The principal aim of this paper is to examine the various options concerning the metaphysics of natural kinds, in particular as regards their ontology. Initially proceed by posing a series of questions whose positive answers correspond to a sequence of increasingly metaphysically committed views about natural kinds. In section 2 these questions concern the naturalness and kindhood of natural kinds. This leads, in section 3 to the question whether natural kinds are themselves genuine entities. In section 4 I present an argument for a positive answer to the existence question, that takes essentialism about natural kinds to imply their existence: (having an) essence implies existence. In section 5 I consider the objection that kind essentialism reduces to individual essentialism, which would undermine the import of the essence-implies-existence argument. In sections 6 and 7, I put this machinery to work, asking first what sort of entity a natural kind may be (e.g. a set, an universal, or a *sui generis* entity), and, finally, how homeostatic property cluster view fares when compared to the general conception of natural kinds developed in the preceding sections.

2 Natural kinds and classification

In this section I introduce the metaphysics of natural kinds with what is the least metaphysically loaded question concerning natural kinds, that concerning the existence of genuinely natural divisions in the world. I shall argue that discussions of this question often lose sight of a second, arguably more important question, whether these divisions are divisions into kinds.

Socrates, in a famous quotation from Plato's *Phaedrus* (265d–266a), enunciates two principles; the first of which is that a speaker should define his notions, and the second of which is "that of division into species according to the natural formation, where the joint is, not breaking any part as a bad carver might". John Stuart Mill, who introduced the term 'Kind' (usually with a capital 'K' in Mill's text, and later expanded by John Venn (1866) to 'natural kind')[1] expresses a similar thought, "In so far as a natural classification is grounded on real Kinds, its groups are certainly not conventional; it is perfectly true that they do not depend upon an arbitrary choice of the naturalist" (Mill 1843: 720). The central issue here concerns one's response to the following question:

> (Q1) Is the world such that there are genuinely natural divisions and distinctions, i.e. that there are natural differences and similarities between things (and if so what accounts for such differences)?

Socrates gives a positive answer to the first part of (Q1), thus asserting the view that I call *weak realism* about natural kinds—that there are natural divisions among things such that our actual categorizations can succeed in matching those divisions (or fail to), whereas Mill's discussion of 'natural classification' is committed to what I denominate *naturalism*: the view that many of our actual categorizations into natural kinds, especially those of science, succeed in matching the actual divisions in nature. Weak realism is a metaphysical thesis. Mill's naturalism implies weak realism, but adds to it an epistemological claim that we can and do often know what those natural divisions are; that is we can, sometimes, knowingly succeed in following Socrates' exhortation to match our actual categorizations to those in nature.

It would in principle be possible to argue for weak realism without committing to naturalism. A Kantian view might hold that we are unable to discern which the actual divisions in nature are, but nonetheless might also maintain that the existence of such divisions is a condition of the possibility of differentiated experience. Kuhn expresses something like such a thought (Kuhn 1979; cf. Hoyningen-Huene 1993: 34). More commonly, an argument for weak realism is a corollary of an argument for naturalism. Thus one may argue for the existence of natural divisions by articulating an argument for scientific realism that focuses on the presence of classifications into kinds in science. Scientific realism tells us that modern science is our best guide to what things there are and what they are like. Furthermore, science is not merely our best guide, but also it is generally, when consensus has been reached, a good if not infallible guide to such things. Natural science does divide things into kinds—kinds of subatomic particle, kinds of chemical element or chemical compound, kinds of crystal structure, clades and possibly species, and other biological kinds, kinds of rock, kinds of star and so forth. If such divisions are not natural then much science has got things massively wrong. Conversely, if science is by and large right, then we can have a high degree of confidence that the divisions science draws are genuinely natural.

As the quotation from Mill indicates, the view opposing naturalism is that our classifications in the sciences are 'arbitrary conventions'. Conventionalism (cf. Hacking 1999; Kukla 2000) holds that the divisions we think of as natural, including those of science, are mere social constructions, reflecting particular human inter-

[1] See Hacking (1991) for a historical survey.

ests rather than the structure of reality. The argument from scientific realism suggests that one can take the naturalism versus conventionalism debate to be a reflection of a more general debate concerning scientific realism. The simple claim of conventionalism that scientific interests are just one set of interests among many other human interests and should not be awarded priority, is far from sufficient to ground conventionalism. This is because the interests of science are a particular set of interests—the interests of describing, explaining, understanding, and predicting the *natural* world. It is precisely because the categories of some field of science are tailored to these interests concerning what is natural, that the explanatory and predictive success of that field is a reason to believe that its categories do often pick out natural divisions. I shall not pursue that argument further, since its soundness depends on issues concerning scientific realism that have been very much discussed elsewhere (see Psillos (1999) for a now classic survey and discussion).

The realist argument for naturalism (and hence weak realism) is typically expressed with a more specific focus on *induction*; natural kinds are essential to the inductive component of science (Mill 1843; Quine 1969). Our success in inducing predictively confirmed generalizations—protons attract electrons, potassium is more reactive than sodium, members of the family *Felidae* are carnivorous, and so forth—allows us to infer the genuineness of our natural categories.[2]

The problem with this simple association of natural kind classification with inductive success is that it promotes an overly liberal conception of natural kind. Many successful inductions concern natural *relations* between objects (such as the separation of objects and the forces they exert on one another) but entering into a natural relation typically does not form any basis for grouping entities into a natural kind.[3] Quine (1969) asserts that any natural similarity can form the basis for a natural kind. Thus things sharing the same colour form a kind (albeit a kind that might be eliminated by a more sophisticated science[4]). If we agree that natural properties are essential to induction, then natural kinds will be essential to induction on Quine's liberal conception of natural kind according to which there is a kind for every (induction-supporting) respect in which two objects can be similar.

But as Mill (1843: 122–3) pointed out, eighty-five years before Quine's essay, normal usage is more restrictive than this; we do not normally regard all white things as belonging to a common kind. The same goes for more scientifically respectable qualities, such a positive charge. Positively charged items include top quarks, protons, hydronium ions, charged macromolecules, balloons rubbed on a jumper, and the Sun. But such items do not form a kind.

[2] In this paper I do not address questions concerning the structure of natural kind classifications. Do natural kinds always come in hierarchies? If so, does any given natural entity belong at most to one hierarchy (monism)? Or could an entity belong to more than one system of natural classification?

[3] I say 'typically', because I do not wish to assert that kind membership is an intrinsic property of an entity. Often it is, but membership of a biological kind may well depend on origin, which will be a relational rather than intrinsic property of an object.

[4] Quine (1969: 137–8) does remark that, "In general we can take it as a very special mark of the maturity of a branch of science that it no longer needs an irreducible notion of similarity and kind." But Quine is not referring to the elimination of kinds specifically but rather to the elimination of qualitative properties, such as colour, in favour of quantitative ones, such as mass.

Not only would the liberal conception of kind violate normal usage, it would close off philosophical discussion of the validity of a more restrictive notion of kind. On examination, it may turn out that there is no role for a more restrictive kind concept. But that needs to be argued for rather than stipulated. This question is obscured by the fact that (Q1) is more commonly phrased as: "Is the world such that there are genuinely natural divisions of things into kinds?" The tendency is to answer this question in the manner outlined about, by seeking to establish (or refute) the claim of *naturalness*, and thereby the ignore the issue of the division into *kinds*. With Mill's point in mind, we see that even if we give a positive answer to (Q1), we must address an additional question:

> (Q2) Are our natural kind classifications really classifications into *kinds* (and if so what makes them kinds)?

Given the more restrictive, and intuitive, notion of kind that Mill employs, which distinguishes kinds from natural properties, we can see that Mill's own argument from induction needs supplementing. For Newton's laws of motion and gravitation mention no kinds but do refer to natural quantities; and these laws provide some of the most spectacular examples of inductive success. Likewise, we can make successful inferences with more mundane inductions, such as the observation that dark objects heat up quicker in the sun than light-coloured things, without referring to kinds. Indeed the world could lack kinds, yet successful inductions could still be possible. One could imagine a Newtonian world in which there is a basic stuff that can have continuous range of masses and a continuous range of charges, such that any value of charge can be associated with any value of mass. In such a world there would be no kinds, but there would be natural divisions (e.g. between the positively charged things, the uncharged things, and the negatively charged things; or between the things with mass of 10kg or more and the thing with mass less than 10kg. And there would be inductions that one can make about the behaviours of substances, on the basis of Newton's laws of motion and gravitation and Coulomb's law.

So natural kinds are not essential to induction in general. Nonetheless, may not kinds be essential to *some* inductions? Does not the success of those inductions that *do* use natural kinds show that the the natural kinds reflect genuine divisions on nature? Even in specific cases, it is not clear that the kinds are essential. The reason why is that for kinds to be essential for induction, it must be the case that the induction could not be done without them. And the fact that we do use kinds does not show that we *must* use kinds. Perhaps certain underlying properties are doing work of the induction, properties that are not themselves kind-implying. For example, take the inductive generalization that protons attract electrons; this is just a particular case of the inductively known fact that any positively charged object attracts any negatively charged object (or, more generally still, is an instance of Coulomb's law). Likewise, what explains why potassium is more reactive than sodium is that reactivity in metals depends on how easily they lose their valence electrons, and for metals such as sodium and potassium, with a single valence electron in their outer shells, the larger the atom, the less easily that electron is held by the nucleus. In these cases, the kinds *per se* play little role. Rather, what underwrites the induction are facts about (non-kind) properties associated with kinds. In that sense, kinds are not essential to induction—with sufficient and appropriate knowledge, it is plausible that we could carry out all induction on the basis of correlations between properties.

The requirement that kinds be essential to induction is, however, too strong. The fact that kinds may, in principle, not be essential to induction, ought not be taken as an argument for eliminativism about kinds. For it may remain the case that the removal of natural kinds from science would lead to a considerable diminution in inductive and explanatory power. Eliminativism would only be justified if our best science were to do without kinds without violating science's usual preference for explanatory power. An explanationist view of confirmation would take any loss of explanatory power that was brought about by a forced elimination of kinds as itself a reason for believing in natural kinds in addition to natural properties. A full account of natural kinds will therefore need to show how appeal to natural kinds provides explanatory power that is not available to natural laws and properties alone. We will bear this in mind when we return to the question, what *are* natural kinds. Let us distinguish between *non-kind properties* and *kind properties* (while admitting that the distinction might be vague). Kind properties are properties that concern belonging to a kind, e.g. the property of being gold, or the property of being a horse, whereas non-kind properties are those that do not involve kind membership, such as having density of 19.3 g/cc, engaging in such-and-such characteristic reactions, having a face-centered-cubic crystallline structure, or the property of being herbivorous, of giving birth to live young, and so forth. It should be noted that it would be near impossible to conduct biology or chemistry on the basis of non-kind properties alone. This reflects the inductive and explanatory power that reference to species, elements, compounds, and so forth gives us. Mill (1843: 703–4), again, points to this fact, when he tells us that "The class horse is a Kind, because the things which agree in possessing the characters by which we recognise a horse, agree in a great number of other properties, as we know, and, it cannot be doubted, in many more than we know." Sufficiently precise knowledge of the melting point of a chemical element predicts exactly which element it is and thereby all its other, non-kind properties; the same can be said of many other properties of an element. Let us say that there are n non-kind properties associated with a natural kind. There will then be up to $\frac{1}{2}(n^2 - n)$ inductive generalizations linking these properties; whereas, if we add the property of belonging to the kind, we can capture all these relations in n inductive generalizations, each of which relate a non-kind property to the kind property.

To conclude: we started with a well-known question, the *naturalness* question concerning natural kinds. This question asks whether our natural kind predicates mark genuinely natural distinctions in the world, (Q1). The fact that such predicates are a central feature of successful scientific theories and explanations, gives us reason to think that they do. Such a reason derives from more general considerations of scientific realism. For us to have such grounds does not require that natural kinds are essential to induction, but simply that the explanatory power of science would be significantly reduced without them. This is just as well, since these considerations, as they stand, concerning natural kind predications fail to distinguish them from natural *property* predications. Thus we are led to a second, arguably more pressing and rather less discussed question than the naturalness question, which is the *kindhood* question, whether our natural classifications include a distinct set of classifications into kinds, (Q2). An account of natural kinds must account for both their naturalness and the fact that those items falling under a natural kind predicate form a kind. The prevalent discussions in the literature refer to the role of kinds in induction succeed in answering the naturalness question: natural kinds are natural because they are grounded in properties that support inductive inferences. They thereby answer the naturalness question without answering the kindhood question. Any satisfactory metaphysics of natural kinds must address the kindhood question in addition. The answer to (Q2) we find in Mill is that we have a natural kind rather than a mere class of naturally similar objects when such a classification is the source of particularly strong inductive and explanatory power. Later is this paper we will return to this issue in more detail.

3 Natural kind realism—existent natural kinds?

Let us assume that we have given positive answers to (Q1) and (Q2): there are natural divisions in the world, and furthermore there are natural divisions into kinds. Although metaphysically significant, such claims do not imply a positive answer to the following ontological question:

> (Q3) Are there entities that are the natural kinds? Are natural kinds required as part of our ontology?

'Strong realism' is the view that gives a positive answer to (Q3), regarding natural kinds as genuine entities. It is 'realism' by analogy with realism about universals (and about possible worlds and theoretical entities), since it is ontologically committed. It is 'strong' in order to contrast with the common use of 'realism' to denote the metaphysical component of naturalism, i.e. the view that there are natural divisions of nature into kinds. That thesis has no immediate ontological commitment, but in order to retain the link with that existing usage I have called this thesis 'weak realism'.

Richard Boyd (1990, 1999a), for one, answers (Q1) and (Q2) positively while giving a negative answer to (Q3), and so is a weak realist about both classification and kinds, but is not a strong realist. E. J. Lowe (1989, 2006), on the other hand, is a strong realist, asserting that we do require natural kinds in our ontology, indeed as a basic component thereof.

According to Boyd, talk of the reality of a natural kind signifies nothing but the contribution that talk the kind makes to the 'accommodation' of inferential practices to causal structure:

> [W]hat is misleading about formulations in terms of the "reality" or "unreality" of kinds, or of the "realism" or "antirealism" about them, is that they wrongly suggest that the issue is one regarding the metaphysical status of the families consisting of the members of the kinds in question—considered by themselves—rather than one regarding the contributions that reference to them may make to accommodation. Issues about "reality" or "realism about" are always issues about accommodation. (Boyd 1999a: 159; cf. Boyd 1990)

According to such a view, although natural kind predicates form a special subset of the natural predicates (predicates that mark natural similarities), for all that has been said hitherto it might be that all the ontology that is required for the success of natural kind predication consists of the natural non-kind properties alone. No argument so far discussed has shown that we need any more ontology than natural non-kind qualities and quantities, such as colour, mass, charge, etc.. If so, we do not have to regard natural kinds as any kind of entity, universals or any other.

Lowe has two reasons for adopting strong realism. The first of these is that we do talk about kinds as entities, and indeed we attribute properties to them (Lowe 2006: 29; I consider his second reason later in this section). Natural kind terms can take subject position in predications, and can be quantified over: 'salt dissolves in water'; 'salt dissolves in something'. This forms the basis of a syntactic argument for the existence of natural kinds. Natural kind terms figure as singular terms in true predications and identity statements, and permitting true quantifications. Consider (a) 'Iridium has atomic number 77'. The latter appears to be a predication '. . . has atomic number 77' of a natural kind, and implies (b) 'there is a natural kind with atomic number 77'. Likewise, (c) 'Iridium is the element with atomic number 77' appears to be an identity statement. In each case the statement is also true. If appearances are correct, and natural kind terms are singular terms, then their use in true statements is sufficient to establish the truth of a positive answer to (Q3).

Boyd's view could be interpreted as a kind of ontological eliminativism about kinds. It *sounds* as if we quantify over kinds, but this is mere appearance. The entire content of 'K is a natural kind' is given by some statement about an accommodation (or match) between inferential practices concerning Ks and an appropriate causal structure, a statement that has no ontological commitment to things that are natural kinds. If so, we must give an alternative account of the syntax of the statements (a)–(c), that shows that they do *not* have ontological commitment, despite appearances. If (a) does not have the form <singular term + predicate>, what form does it have? The obvious initial steer is that claims about natural kinds are really claims about the instances of the natural kind. So sentences with the apparent form <Φ(K)>, really have the form <∀*x* Φ*x*> (where Φ*x* iff *x* is an instance of K. But such a proposal quickly runs into trouble (cf. Lowe 2006: 144). Even simple cases give uncomfortable results. Take 'Iridium has atomic number 77'. According to the proposal, this states 'all samples of iridium have atomic number 77'. But that does not make sense—a lump of iridium does not have atomic number 77. Other than the kind itself, only atoms of iridium have an atomic number—and strictly even that is false since atoms don't have an atomic number, they have a *nuclear charge* (which is equal to the atomic number of the element of which they are atoms). At the same time, not every statement about the kind is a statement about the atoms of the kind: 'Iridium has a density of $19\ \mathrm{g\,cm^{-3}}$ and a melting point of 2739 K' cannot be understood as a statement about the atoms of iridium. 'Iridium is used in the manufacture of high-temperature devices' is not a statement about *all* samples of iridium, but rather implies something only about *some* samples of iridium. And many statements about iridium have no clear implications for samples of iridium at all, for example: 'Iridium has two naturally occurring isotopes', 'Iridium is one of six platinum group metals, and the rarest'. So, statements about a kind are not equivalent to generalizations over samples of the kind. But nor is there in any other way of translating statements about kinds into statements about samples. This suggests that natural kind terms are indeed genuine singular terms, rather than disguised quantifiers of some sort. Given that such terms occur in true statements we may conclude that they are successfully referring terms. The referents are the entities that are the natural kinds.

A common response to such a position is fictionalism. While we readily assert statements such as 'Iridium has a density of 19 g cm^{-3}', we are not fully committed to their truth, and that is because we are not committed to their ontological consequences. While fictionalism may be well-motivated as applied to mathematics, the motivation with respect to natural kinds is rather weaker. There is no reason to suppose that natural kinds would, if existent, be metaphysically troublesome in the way that one might suppose numbers and sets are. The latter would be acausal and thus suspect as regards being objects of knowledge and reference. But there is no reason to suppose that natural kinds fall foul of this kind of objection any more than concrete universals.

If fictionalism is not well motivated, then deflation seems to promise an account that adheres to the syntactic argument while also interpreting its conclusion in a manner that is in the spirit if not the letter of Boyd's rejection of natural kinds. The neo-Fregean view in the philosophy of mathematics (Wright 1983; Hale 1987) supplements the syntactic argument with an *a priori* equivalence between statements employing referring terms and those which do not. Consequently, thanks to Hume's principle—($N^=$) the number of Fs is the number of Gs iff the Fs and Gs are equinumerous—facts concerning numbers may be considered in a deflationary way as reflecting facts concerning equinumerosity among concepts. Someone such as Boyd who thinks that the reality of natural kinds just comes down to the possibility of inductive accommodation might very well be willing to concede that natural kinds are genuine entities while also maintaining that their existence merely reflects facts about accommodation (rather as directions are objects, but their existence is a shadow of facts about facts about parallelism between lines: ($D^=$) the direction of line **a** is the direction of line **b** iff **a** and **b** are parallel. Frege 1986: 76–8). The difficulties with such views are much discussed, but all face the following problem. If the left hand side of ($N^=$) or ($D^=$) is committed to the existence of entities (numbers, direction) and the right hand side is not, then how can the left hand side be a mere reflection of the state of affairs described by the right hand side? If on the other hand, the right hand side is also committed to the existence of entities, how can this view be deflationary?

To sum up, the syntactic argument for strong realism can resist any systematic attempt to eliminate apparently ontologically committing reference to or quantification over kinds. We must take the apparent quantification or reference to natural kinds seriously. Fictionalism is an option less well motivated with respect to natural kinds than it is with regard to other sorts of putative entity. Deflation along the line of neo-logicism remains an option, but a highly contentious one. So the syntactic argument looks promising. But the argument has a downside, in that it reveals nothing about the nature of natural kinds. Nothing in the argument turns on natural kind terms being kind terms, let alone natural kind terms; it reflects little more than the fact that these are singular terms used in true sentences. An argument such as that given for the natural kind *iridium* might also be given for the non-natural kind *trash*, and so, furthermore, without giving any insight into the appropriate response to questions (Q1) and (Q2).

E. J. Lowe does present a second argument for strong realism, by holding that a particularly important case where properties are predicated of natural kinds are statements of the laws of nature. Indeed, Lowe holds that *all* laws involve characterizing natural kinds in this way.

If this argument is not to be simply the application of the syntactic argument to a particular case where natural kinds singular terms are used, then it must be that the mention of natural kinds in the laws of nature is ontologically particularly revealing, in a way that goes beyond just any appearance of natural kind terms in true statements. The metaphysical significance of the laws of nature lends some support to that perspective—the explanatory role of the laws of nature provides them and their components with a more substantial mode of existence than is generated by the syntactic argument alone. But for such an argument to hold up, it must be that the natural kinds are not easily eliminated from the relevant laws—reference to natural kinds is genuine since no substitution is able to render an equivalent law.

The claim that all laws of nature involve natural kinds is false. We have seen that many laws, such as Newton's, invoke no kinds at all, but require natural properties (including quantities) alone. Nonetheless, the argument would succeed if *some* laws of nature re quire the existence of natural kinds. But showing this is not straightforward. Does the fact that the law that protons attract electrons invokes the kinds *proton* and *electron* show that those kinds really exist? If we were to construe the law as a relation between to entities it would seem so at first sight. However, the rejoinder to this points out that the law involved here is Coulomb's law and that law related natural quantities (charge, separation, force) not natural kinds. We should not think that there are two laws, Coulomb's law plus the law that protons attract electrons; the second, apparent law, is just a manifestation or facet of the first. So in this case, the apparent reference to natural kinds gets us no further than the syntactic argument. Are there laws for which such an eliminative manoeuvre is not possible? It is not obvious that there are. Chemistry is a science replete with natural kinds. Yet, the laws of chemistry, such as they are either do not invoke kinds at all, or permit the manoeuvre just illustrated. For example, Henry's law, that the solubility of a gas is proportional to its pressure, is a typical law in chemistry, but does not require the existence of kinds. Gay-Lussac's law, that the the ratio of the combining volumes of gases is always a small whole number requires that there are differences between natural kinds—weak natural kind realism—but does not require the existence of kinds themselves. A law that mentions specific natural kinds, such as 'potassium is more reactive than sodium' might seem a better option for this argument, since it refers to specific kinds. Note, first, that it would not be usual for a chemist to regard this as a *law*. The generalizations called 'law' in chemistry are laws such as Gay-Lussac's law and Henry's law, mentioned above, or Dalton's law of partial pressures, Faraday's law in electrochemistry, the law of definite composition, the periodic law and so forth. While many of these laws require differences between kinds, that requirement is satisfied by weak natural kind realism and so the existence of these laws does not entail ontologically committing strong realism. Even if ‘potassium is more reactive than sodium’ is regarded as a law, a similar response is available. For what underwrite this ‘law’ is the fact that group I elements (which include potassium and sodium) react by donating their single outermost electrons, which occurs more readily when that electron is more weakly held. The electrons are more weakly held when they are more distant from the nucleus, as is the case for potassium in comparison to sodium. This explanation rest general laws (such as Coulomb’s law of electrostatic attraction) and specific facts about sodium and potassium that do not require the existence of those kinds as entities but require only that they are naturally similar and different in certain respect (similar in that all atoms of both kinds have a single electron in their outer shell, different in that all neutral atoms of potassium are larger than atoms of sodium). When we move from chemistry to biology, we find even fewer laws, if any at all (Smart 1963). But if there are laws, for example the Hardy-Weinberg law (Ruse 1970), they appear to be amenable to the same treatment as was given to the laws involving kinds found in physics of chemistry.

The syntactic form of ‘potassium is more reactive than sodium’ plus the fact fact that the statement is true, do indeed give us reason to think that there are entities that are potassium and sodium. This is the syntactic argument. But the fact that the statement is a statement of natural law provides no distinct argument for the existence of the natural kinds. Laws of nature require natural differences and these difference may include kind differences (e.g. there being a difference between samples of sodium and of potassium), but that suffices only for weak realism. Might not a combination of the syntactic argument and Lowe’s argument yield an argument for the existence of kinds (the syntactic argument) plus the claim that these entities are natural entities and kind-like? Lowe’s argument from the laws of nature has a clear connection with the Mill–Quine argument from induction. On the one hand it suffers from similar problems, in that laws, like the capacity to support induction do not suffice for kindhood, since there are laws that do not involve kinds at all. At the same time, the law argument fares worse than the induction argument, since the capacity to support induction is a necessary condition of being a kin but participation in laws is not. For there are many kinds (e.g. those in biology) that are not involved in any laws of nature.

Thus we have, so far, only the syntactic argument for the existence of entities that are the natural kinds. And while that argument may be able to resist certain criticisms, the argument is of such a general nature that it provides no insight into the nature of natural kinds. That means that this argument for the existence of natural kinds in general generates no constraints on which entities natural kinds might be, e.g. whether they might be sets, classes, universals, etc.. In the next section I present an argument that does provide such a constraint.

4 From natural kind essentialism to natural kind realism

We have considered what it would be to take the ontology of natural kinds seriously. While we have a syntactic argument for strong realism, it provides little insight into the metaphysics of natural kinds. A more useful argument would provide some insight into or constraint on what sort of entities natural kinds are. In this section I provide just such an argument. That argument proposes that one reason for assenting to strong realism is the fact that natural kinds have essences. As Kit Fine (1994) emphasizes, essences concern the nature or identity of a thing, and in so doing follows a tradition that includes Locke, for whom an essence is "the being of any thing, whereby it is what it is" (*Essay* Bk.3, Ch,3, §.15), and Aristotle. Since only what exists can have a nature or identity, natural kind essentialism implies (strong) natural kind realism. As the quotation from Locke makes clear, essence implies existence in the sense that only for what exists could there be something, the essence, that is its being 'whereby it is what it is'. In short: essence implies existence.[5]

It might be thought possible to be an essentialist about entities whose existence one doubts or even rejects—for example an atheist might agree that the essence of God includes beneficence or omnipotence; likewise one might think it is part of the essence of phlogiston that it is emitted in the process of combustion, even though one knows that there is no such kind. It is worth remembering that one can reasonably hold that a kind can exist even if it has no instances—some of the transuranic elements may be like this. It is the existence of the kind that is at stake here, not the existence of instances of the kind. But in the case of phlogiston one ought to deny the existence of the kind also. In my view such essences (if essences at all) are nominal rather than real essences, and the principle enunciated in the previous paragraph applies only to the latter and not to the former.[6] If there really is a God, it is not at all clear that God's real essence does include beneficence and omnipotence, even if God does possess these properties. The point is perhaps easier to see with respect to phlogiston. Let us imagine that current chemistry is a horrible mistake, and that the phlogiston theorists were right all along. There is a substance which explains combustion by being given off in that process; that substance is phlogiston. But does that substance have an essence that includes being emitted in combustion? It would be a matter of scientific investigation to discover whether that is the case. Quite plausibly science would discover some quite different essence. For example, it could turn out that phlogiston is a complex substance, composed of more basic components joined in some specific structure, and that it is this composition and structure that explain the facts of combustion. In that case we would regard the composition and structure as constituting the essence of phlogiston, not its combustion-producing capacity (just as we regard the essence of water to be H_2O, not its salt-dissolving or thirst quenching properties). Thus I do not believe that real essences can in general

[5] Not in the Cartesian sense that the *content* of the essence of God implies that God exists. Rather, the fact that some *x* has an essence implies that *x* exists.

[6] Or we may regard the essences as real essences of the *concepts* of God and phlogiston—but then there is no problem with the principle, since the existence of the concepts is not in doubt.

be known *a priori*—any exceptions, such as sets and numbers, would be entities whose existence can also be known *a priori* also. The claim that essence implies existence would deny that it is essential to Sherlock Holmes that he does not exist. Kripke (1980: 156–8) himself argues that there could not be anyone who is Sherlock Holmes, and likewise that there no possible species that is the unicorn. Is it not then essential to unicorns that they are mythical? No; this would be to infer an essentialist claim from a necessary truth, an inference we should reject for well-known reasons articulated by Fine, and which I mention below. And while Kripke is often quick to move between necessities and essences, he does not do so here. He says, "Just as tigers are an actual species, the the unicorns are a mythical species." It is not essential to tigers that they are an actual species, though it is necessary that they are an actual species (taking 'actual' to be a term referring to the actual world). Likewise, although it is necessary that unicorns are mythical, it is is not essential.[7]

The argument that essence implies existence is premised on the idea that an essence concerns a thing's nature or identity. Nonetheless, many of the arguments for natural kind essentialism imply a weaker conception of essence, as a necessary property. Thus in discussions of natural kind essentialism that follow the paths of Kripke and Putnam, it has generally been held to be sufficient to establish an essence for a natural kind that one show that a certain feature is possessed by all instances of a natural kind in every possible world, for example:

(N) in all possible worlds, all samples of water are samples of H_2O.

However, we cannot read off any genuine essentialist conclusion from assertions of the form of (N), despite the fact that it is common to make the move from (N) to:

(E) water is essentially H_2O,

and, *mutatis mutandis*, for other necessities. Fine (1994: 6) points out that we can construct many predications that hold necessarily of some item yet do not denote any part of that item's essence. For example '. . . is such that 2 is a prime number' holds necessarily of any object, but does not capture any part of any object's essence (except that of the number 2 itself). Let us call an 'improper essence' an essence which is implied by the corresponding necessity, and a 'proper essence' one that is not.

Our problem is that insofar as Kripke–Putnam arguments do establish the conclusions concerning necessity, as presented they establish only improper essences but not proper essences. However, in order to support the conclusion that there exist natural kinds, we need proper rather than improper essences, since improper essences (as Fine's examples prove) tell us nothing concerning the nature or identity of the entity concerned.

Nonetheless, the Kripke-style arguments need little by way of supplementation to show that they do reveal proper essences. Fine (1994: 8–9) tells us concerning a necessity that arises from an essentialist attribution that "the resulting necessary

[7] Of course, this leaves it open that it is essential to the concept *unicorn* that it is the concept of a mythical creature. But that is consistent with the essence implies existence thesis, since that thesis would imply on the existence of the concept *unicorn*, which is not in doubt.

truth is not necessary simpliciter. For it is true in virtue of the identity of the objects in question; the necessity has its source in those objects which are the subject of the underlying essentialist claim." So if a claim such as (N) does have its necessity in virtue of the identity of relevant entities, then we are entitled to infer the truth of the corresponding essentialist claims, such as (E). Is that in fact the case for (N) and the like?

One may hold that the arguments for natural essentialism proceed by analogy with Kripke's arguments concerning the identity of particulars: 'water is H_2O' is understood to be analogous to 'Eric Blair is George Orwell', and the necessity of both is the necessity of identity. Such an argument establishes a certain necessity:

(I) necessarily, water is H_2O

by considerations directly concerning identity. So there is no obstacle to maintaining that what has been established is essential as well as necessary.

The problem with such an argument is that it so manifestly assumes that the kind water is an entity whose identity is under discussion. Doubts may be raised about the argument precisely because the analogy with identity is questionable. If so, it looks as if this route to natural kind realism will be question-begging.

Alternatively one might regard the necessities in question as being established by the Twin-Earth thought experiments of Putnam (1975) and similar arguments from Kripke (1980). While some of those arguments, Putnam's especially, have a semantic air to them, that aspect can be stripped away so that the arguments can be seen for what they really are: appeals to metaphysical intuition concerning samples or examples of the kind in question.[8] Such arguments do not reach (N) via (I), and indeed those arguments are consistent with the denial of (I). For example, intuition tells us that samples of water-like XYZ on Twin-Earth are not samples of water, leading us to assert (E); yet one might deny (I), for example because one denies that ice is water or that a single H_2O molecule is water.

Since these arguments rest upon the deliverances of intuition concerning samples of the kind, there can be no complaint that the argument clearly assumes what it sets out to prove, that the kind in question is an entity. It might be that in some way metaphysical intuition implies such an assumption, but that is no objection, for *if* one accepts the epistemic value of the role of intuition here, then the fact that intuition makes such an assumption is a reason to favour that assumption. Furthermore, since the considerations appealed to in the arguments for (N) clearly do concern the nature of water, we are on firm ground in claiming that a strong essentialist (E) is thereby supported.

5 Natural kind versus individual essentialism

The preceding section argues for a conditional claim: if proper essentialism concerning natural kinds is true, then natural kinds are a certain kind of entity. To es-

[8]Barbara Abbott (1997: 312) points out that to "get Putnam's results one does not need to use terms like 'reference ' or 'extension' ... All one need to ask is whether ... such-and-such a substance would be water".

tablish the antecedent of this conditional would require recapitulating the many and familiar arguments concerning natural kind essentialism. I shall instead take essentialism as established but will consider the objection that the essentialism established is really an essentialism concerning the individual items and samples that are the members of the kinds. If so, the argument for kind existence from kind essentialism would reduce to an argument for individual existence from individual essence, which would be no news at all.

Michael Devitt (2005), for example, argues for natural kind nominalism, but does not reject natural kind essentialism (see also Devitt and Sterelny 1999). According to Devitt, natural kind terms do not rigidly designate natural kinds but rather rigidly apply to their instances. That is to say, a natural kind predication applies to a given instance in all possible worlds. A consequence of this is that if an individual is an instance of a kind then it is necessarily an instance of that kind. This is a improper essentialist version of Aristotle's view that if **a** belongs to the natural kind K, then it does so essentially. But what is significant about Devitt's view is that this essentialism about individuals' membership of a kind is identified with essentialism about the kind.

Note first, that a predicate 'F' can apply rigidly without that implying any essence of Fness, for example 'is actually in my room at 12.00 on 5 November 2008' or 'is identical to **a** or identical to **b** or identical to **c**' (where '**a**', '**b**', '**c**' rigidly designate individuals).[9]

More importantly, the claim that all members of a kind have some property, the essence of that kind, is consistent with the anti-Aristotelian claim that some entities can change their kind. An anti-Aristotelian kind essentialism requires only that when they change kind they lose or acquire the relevant kind essence.

The Aristotelian view that kind membership is essential is refuted by the fact that individuals can change their species. Ernst Mayr's biological species concept, for example, takes species to be breeding populations. Consider two subpopulations whose genetic difference is increasing over time so that ever fewer pairs from the two subpopulations can interbreed. Eventually one member of the last pair for which breeding would be possible dies. Now the two subpopulations are reproductively isolated—a speciation event. As Mohan Matthen (2009) explains, this means that whereas before the death of that individual the living members of the two subpopulations were conspecifics, after its death they are members of two distinct species: they will have changed their species in the course of their lives.[10]

[9] Devitt notes in response to criticism by Schwartz that he does not claim that it is the function of rigid designation to distinguish natural from non-natural kinds. However, this criticism is different, since Devitt does regard it as a secondary function of an account of rigid designation that it explain, even if only superficially, the modal features of kind and general terms. Thus while his view does not need to account for the distinction between natural and non-natural kinds, it ought to identify the distinction between those general terms which are associated with essences and those which are not.

[10] It is important to note that species membership is not a matter of genotype. It is true that members of a species will be genetically similar, but there will often be no unique genetic character that they all share but is not shared by anything outside the species. In particular, a certain mutation may in due course lead to a speciation event, but the arrival of that mutation cannot itself be regarded as the arrival of a new species, at least not for sexually reproducing species. The organism with the new mutation will need to breed with organisms without it. If the mutated organism is the first member of the new species,

Other biologically plausible conceptions of species have the same result, that an individual may change its species. Of course, the picture presented above is an idealisation. The capacity to breed with fertile offspring is a vague matter, and it may be preferable to present speciation as a process rather than an event at a point in time. In which case belonging to a species may be a matter of degree. Even if this vagueness were consistent with the Aristotelian view, it remains the case that an individual will be able to changes its degree of belonging to a species, which would be inconsistent with the Aristotelian view; furthermore, a particularly long-lived individual may change degree from the highest degree possible to the lowest.

It would be possible to respond that while the Aristotelian claim is false, it is also false that species so conceived have essences either. Conversely one might reject species as kinds, for example by adopting a cladistic approach to biological classification, according to which organisms are grouped together according to common ancestry. If we take origin to be essential, then it will be an essential fact concerning some organism that it is descended from some other organism O. If we define a biological clade C as those organisms descended from O, then it will be part of the essence of every member of C that it is descended from O, i.e. that it is a member of C. Thus clade-membership is an essential property of individuals, and thus obeys the Aristotelian conception of individual essence. In this case individual essence will align with kind essence, since the essence both of the kind and of the individual is a matter of ancestry. Thus depending on what approach one takes to biological kinds, we may reject or accept the Aristotelian claim, and one may maintain or break the relation between individual and kind essence. The next example shows how the latter pair can come apart.

In this example a heavy atomic nucleus changes its kind when it undergoes alpha or beta decay. For example, a nucleus contains 92 protons and 146 neutrons; it emits an alpha particle, and as a result the nucleus now contains 90 protons and 144 neutrons. Or a nucleus with 55 protons and 82 neutrons emits a beta particle (an electron) and becomes a nucleus with 56 protons and 81 neutrons. In such cases, the kind of the nucleus is governed by the number of its protons (although the isotopes, governed also by the number of neutrons, are also kinds, subkinds of the elemental kinds). In both cases the decay processes described lead to new kinds (a uranium nucleus yields a thorium nucleus, and a caesium nucleus yields a barium nucleus). And it is natural in each case to regard the nucleus as having retained its identity in the process—in the beta decay case, the nucleus loses only four millionths of its mass. So we have change of kind with retention of identity, against the Aristotelian claim; nevertheless the kinds themselves have essences (the elemental kinds having the number of protons in the nucleus as essential). One response to this case is to deny that there is continuity of identity—decay leads to a new nucleus, not a change

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then its offspring from mating with a non-mutated member of the old species will be members of which species? Furthermore, since mutations are frequent, the arrival of not just any mutation will create a new species; it will have to spread throughout a significant subpopulation, leading to splitting of the original population. If the mutation is the speciation event, then whether or not it counts as a speciation event will depend on subsequent events—the spreading of the mutation and the splitting of the populations. In which case whether or not an organism belongs to species S at *t* will depend on events occurring later than *t*, which seems at least undesirable.

in one and the same nucleus. That denial may be backed by the thought that repeated further processes of decay might bring about nuclei very different from the original one. Would we want to say that some very light nucleus is the very same nucleus as the heavy uranium nucleus with which we started? Nonetheless, this problem does not originate with the issue of crossing kind boundaries. For an analogous problem arises when we consider small changes to any entity *across worlds* which may taken together cast doubt on the identity of the first and last items in the series—even if there is no change in kind. One may expect a solution to the latter to apply to the former case. Thus, for example, counterpart theory avoids the problems raised by so-called transworld identity because the counterpart relation is not transitive. There is no reason to suppose that particulars of different kinds cannot be transworld counterparts; likewise they can be intra-world cross-temporal counterparts also. In the case where the ^{238}U nucleus emits an alpha particle and yields a ^{234}Th nucleus it is plausible to regard the latter as the counterpart of the former—it is certainly the object that shares more of the properties of the former than any other.[11]

The nuclear fission case shows at the very least that there is no obvious incoherence in denying the Aristotelian claim while maintaining essences for relevant kinds.[12] I suggest therefore that facts about kind essences are not logical consequences of facts about individual essences. Therefore, the fact the kinds appear to have essences is not to be explained by the fact that individual instances of those kinds have essences, and therefore if essentialism about some kind can be taken to imply the existence of some entity that entity is the kind, not an instance of that kind.

Devitt's notion of rigid application was introduced in order to supply the appropriate analogue for general terms to Kripke's notion of rigid designation as applied to individuals. Kripke treated natural kind terms along with singular proper names as regards rigid designation, but supplied no account of what precisely this could mean for a natural kind term. The worry is that if any sense can be made of this at all, it leads to triviality—every general term will designate rigidly (c.f. Marti 2004). This problem arises because those concerned about the semantics of general and kind terms have focussed on predicates ('is gold', 'is a red squirrel'), assuming that an analogue of the reference of a singular term would be the extension of a general or kind term. However, in the light of the fact that natural kind essentialism leads to strong realism about kinds, we can see that this approach is unnecessary, for there are kinds to which singular natural kind terms ('gold', 'the European red squirrel') can refer in just the way that names of concrete individuals can, so that an account of rigid designation can be given in just the same way: a natural kind term designates rigidly if it designates the same kind in all possible worlds. Thus 'gold' designates gold rigidly, whereas 'the material of which most wedding rings are

[11] The cross-temporal counterparts are not the four-dimensional objects; rather they are time-slices. Note that David Lewis's motivation for transworld counterparts, the problem of accidental intrinsics is the analogue of his reason for adopting time-slices, the problem of temporary intrinsics (Lewis 1986b: 202–4, 210–20).

[12] Another example of items that change their kind might be stem cells, which are able to become cells of a specific kind that they did not previously belong to. I owe this example to Peter Farleigh.

made' designates gold in this world, but not in all worlds, and so designates gold non-rigidly.

6 Options for natural kind realism

Proper essentialism tells us that strong natural kind realism is true, i.e. that natural kinds are entities. But what kind of entities? Strong realism may itself be subdivided according to how it sees kinds in relation to other entities. Our fourth question may be posed thus:

(Q4) Are natural kinds:

(a) Identical or straightforwardly reducible to entities of a more general nature, for example sets or (non-kind) universals?

(b) Emergent entities, not reducible to other entities, but supervenient on them?

(c) Fundamental, *sui generis* entities?

Option (b) is negative: natural kinds are not fundamental nor are they reducible to anything else. The emergentist option should therefore be considered only once the other options have been properly investigated and found wanting. Exemplifying option (a), Quine and Lewis take natural kinds to be sets and classes respectively. Brian Ellis (2001) regards natural kinds as a subspecies of universals, as does David Armstrong. Lowe's strong realism, on the other hand, is fundamentalist, (c)—not only do natural kinds exist, they constitute a basic category within his four category ontology (Lowe 2006).

The claim that natural kinds constitute a fundamental category can be rejected by considering the fact that science does not give us a reason to suppose that the fundamental laws of nature concern natural kinds. Consider the complete supervenience basis for all actual facts. The question is whether this basis includes natural kinds. If it does not, then we can reject the idea that kinds are *sui generis*, fundamental entities. Of course, there are debates about what this basis must include. Nominalists will admit particulars but not universals. Bundle theorists will take the reverse view. But let us take a generous view and see whether there are ground for admitting natural kinds. So we admit both particulars and universals into our basis, and the facts concerning their combination. What else is required? Armstrong (1983) maintains that we need to include also the (fundamental) laws of nature, whereas to Lewis's Humean supervenience thesis, the distribution of particulars and properties fixes the laws of nature. There may also be debates concerning negative or totality facts. But once we have included all of the above, we have enough (or more than enough) to characterise the supervenience basis fully. If natural kinds are *sui generis*, they are not particulars or universals. So if they appear in this supervenience basis, it will be thanks to the fundamental laws of nature. But the fundamental laws of classical physics all concern natural quantities (mass, charge, force, acceleration) rather than kinds, and neither relativity nor quantum mechanics looks to differ in this respect. If we fix the particulars in the world, their fundamental properties and relations (which are non-kind properties and relations), the facts (throughout history) relating the kinds and properties/relations, and the fundamental laws governing the properties and relations, then we have fixed the natural kinds also. Two worlds will not differ in their natural kinds without differing also either in the distribution of particulars and their non-kind properties or in the laws governing them.

Now let us consider whether natural kinds can be reduced to some more general species of entity. As mentioned the leading candidates are sets (or classes) and universals. Proper essentialism can help us here, since it puts constraints on what sort of entity natural kinds are.

Quine (1969) takes natural kinds to be sets of a certain sort—they are the sets of objects that share a natural property (cf. Hacking 1993: 284). We have considered the objection that sharing a natural property is too liberal a basis for grouping entities into a natural kind. The issue to be considered here is the identification of kinds with sets: if K is a kind and Σ_K is the set of instances of K, then $K = \Sigma_K$.

This proposal is ruled out by essentialism. The essence of a set is given (in part) by the identities of its members, whereas the essences of natural kinds are not given by the identities of its members. If A and B have different instances at different times or in different worlds then the sets $\Sigma_A \neq \Sigma_B$, but the kinds A and B may nonetheless be the same natural kind. The natural kind does not cease to exist when one of its members ceases to exist. And we are not prevented from identifying an actual natural kind with a natural kind in another possible world that has different members. Hence $K \neq \Sigma_K$.

Such objections are already obvious, but they may be overcome by identifying kinds with more complex sets: K is the set of ordered triples $< w, t, k_{w,t} >$, where w ranges over all worlds, t ranges over all times, and $k_{w,t}$ is the set of all instances (members, samples, etc.) of the kind K at t at w. Then:

(M) x, in world w at time t, is an instance (member, sample) of the kind K iff $\exists y(x \in y \wedge (< w, t, y > \in K))$

According to this account of kinds, membership of a kind is not then the same thing as membership of the set that is the kind. So the objection made above—that sets have their members essentially but kinds do not—fails. Some entity **a** may be an instance of the kind K in the actual world w_0 but not in some other world w_1, which is reflected in the fact that **a** will be in some set $k_{w_0,t}$ that is a member of a triple that also has w_0 as a member and which is itself a member of K, while **a** is not in any set that is a member of a triple that both has w_1 as a member and is a member of K.

The move made above does make kinds sempiternal, necessary beings, and so although our earlier problems are obviated, others may arise if one thinks that natural kinds can come into existence, as one might think if species are natural kinds, or may fail to exist in certain worlds. On the other hand, one might regard 'comes into existence' and 'fails to exist at w' as *façons de parler* whose real meaning is 'has an instance for the first time' and 'has no instances at w'. A deeper objection is the observation that although (M) is a necessary truth, it fails to give the right kind of essence for K. If K were this set, then its essence is given by the fact that it has certain sets (the various $< w, t, y >$) as its members. We can construct a set K* akin to some K that has the same structure (it is a set of triples of worlds, times, and sets of particulars existing at those worlds and times), but which fails to correspond to any natural division. Such sets will have entirely analogous essences, but will not be natural kinds. This suggests the following three objections. First, we will be unable to explain why natural kinds play a distinctive role in science (what is it in the nature of K that explains its ability to play a role in science, whereas K* does not?). Secondly, natural kind essentialism will be almost trivial (kinds have essences since sets do), but essentialism is not proven that easily. And thirdly, this essence is of the wrong sort—if natural kinds have essences they will be essences determined by science, and will concern matter such as the chemical constitution of samples or the biological origin of organisms, not the membership of sets.[13]

Another suggestion for the identity of kinds is that they are universals. This is distinct from the above suggestion so long as universals are not sets or classes. It is tempting to construe universals as functions from worlds (or worlds and times) to sets of instances. Similarly, Lewis (1986b: 50–61) takes (abundant) properties to be classes of entities, including entities existing at other possible worlds. Natural properties are a subset of these properties, and so are also classes. Such views concerning properties lead to very similar problems to those articulated above, and so universals cannot be identified with properties thus construed.

Let us therefore take universals to be *sui generis* entities. Could kinds be universals? We may apply the same strategy for answering this question as we did above for sets. Do universals have essences that are of the right sort for being the essences of natural kinds? This question is, however, more difficult to answer than the corresponding question concerning sets, since while the essence of a set is uncontroversial, the essence of a universal is a matter of debate. For example, some philosophers regard universals, fundamental ones at least, as having dispositional essences, which is to say that the essence of some universal is given by is causal or nomic relationships with other universals (Shoemaker 1980; Ellis and Lierse 1994; Bird 2007). Other philosophers regard universals as quiddities, having no essence beyond a primitive identity (Lewis 1986b: 205; Schaffer 2005; cf. Black 2000). Neither of these would seem to do as essences for natural kinds. Since the debate alluded to concerns fundamental, simple universals, that would allow us only to conclude that natural kinds are not fundamental, simple universals. Such a result is not especially informative. If natural kinds are universals, they would be complex, non-fundamental universals. Thus our question now becomes one about the essence of complex universals.

The nature of complex universals is also a matter of debate. Armstrong (1989) and others accept conjunctive universals, but not disjunctive universals. The essence of a conjunctive universal would be that its instantiation by some particular **a** is equivalent to the conjunction of the instantiation of all its conjuncts by **a**. That will not help in cases where the essence of some kind is its microconstitution. For example, the essence of methane is not the conjunction of several prop-

[13] Indeed, the proposal considered make kinds look like the *senses* or *intensions* of kind terms, whereas the kinds themselves should be the *referents* of such terms.

erties associated with methane; rather, the essence concerns methane's being compounded of carbon and hydrogen in a certain way, which seems to be a single but complex property. It will not do to think of 'being methane' as a conjunction of 'being partly composed of carbon' and 'being partly composed of hydrogen' and some other conjuncts. For this would fail to include information about how the carbon and hydrogen are combined and no addition of further universals can provide that. Although he is not concerned with kind essences, Armstrong (1978: 69–71) does argue that there is a *structural* universal that is *being a methane molecule*, whose nature is that it involves the universals *is a carbon atom*, *is a hydrogen atom*, the relational universals *is bonded to*, and *is a part of* in a manner that is not mere conjunction. Lewis (1986a) argues that there are problems with structural universals, whereas Bigelow and Pargetter offer an account that seems to avoid those problems (Bigelow 1986; Bigelow and Pargetter 1989), as does Hawley (2010). This is not the place to examine such theories in detail. However, all participants in the debate agree that any account of structural universals should explain the necessary connections between the being-a-methane-molecule universal and the universals of being-a-carbon-atom, being-a-hydrogen-atom universal, the being-bonded-to relation, and so forth. Strictly, the structural universal we want is the universal of being-composed-of-methane-molecules, but that ought not present any additional problems. If there is such a universal, it might well have the right sort of essence for a natural kind.[14]

The conclusion of this section is the following: if we ground our strong realism about natural kinds in essentialism (the argument that essence implies existence), then that fact provides constraints on what sort of entities natural kinds might be. If natural kinds were sets, then they must have the sort of essence that sets have, likewise for any other proposal for the nature of kinds. That constraint allows us to rule out sets as possibly identical with natural kinds. It also rules out natural properties and universals, when these too are considered as sets or classes. Turning to universals as *sui generis* entities, we can also rule out fundamental universals, since these do not have appropriate essences for natural kinds. Complex universals offer more promising candidates. Here we reach something of an impasse, since there is little consensus on whether complex, structural universals are even possible. That option remains on the table, pending further work. Nonetheless, we have a framework for assessing proposals regarding the nature of natural kinds, which we will put to work in the next section.

7 Homeostatic property clusters

To conclude I shall assess a leading account of natural kinds in the light of the metaphysical debates outlined above. The view of kinds as homeostatic property clusters (HPCs) identifies certain kinds with clusters of properties (Boyd 1991, 1999a,b; Millikan 1999). The idea is that certain sets of properties tend to group themselves

[14] What about kinds that are not distinguished by composition, such as *electron*? In such cases we can consider the properties of an electron as properties of an improper part of the electron, the electron itself. I owe this point to . . .

together. Thus, given all the biological properties there are, some combinations are found together in the same particular on many occasions whereas other combinations are found together never at all or rarely. Consider an N-dimensional space whose axes are the values of the determinable qualities an object might have. This logical space of property combinations is not equally occupied by particulars. Some regions are highly populated whereas others are empty. A feature of biological entities is that no two share exactly the same properties, so no point in logical space is occupied by more than one entity. But two conspecifics (members of the same species) share many properties or have determinate values of qualities that are very close, even if there is no set of properties shared by all conspecifics but not by any non-member of the species.

If we now consider properties relating to variable qualities in a slightly loose way, which is to say that we can consider a range of values of some parameter as a property (so a property can be e.g. a range of body-masses or a range of pelt hues), then we can see that the clustering of *individuals* corresponds to a clustering of up to N *properties* in this N-dimensional space. Adult members of the species *Sciurus vulgaris* (red squirrel) almost all have a body mass of between 400g and 800g, a coat that is black, red, or grey, with a white underside, are 25–30cm in length, have bushy tails and ear tufts, have curved claws, feed on seeds, form a breeding population with other members of the species, are rodents, and so forth. This combination of properties is distinctive of the species, and the nearest comparable combination of properties, those exhibited by the American eastern grey squirrel is clearly distinct, so that the grey squirrels and the red squirrels occupy different regions in logical space.

It is no accident that biological individuals tend to cluster in logical space, and consequently that certain combinations of properties belong together. To begin with, the laws of inheritance ensure offspring tend to be genetically similar to their parents (in some cases almost identical). Thus related individuals are likely to be similar, and conspecifics are significantly more closely related than non-conspecifics. Mutation is a source of difference, but even individuals with mutated genes will not be hugely different from their parents. The laws of development and morphology dictate that significant mutations are unlikely to be viable. Most points in the logical space of combinations of biological properties cannot be occupied because any individual attempting to occupy them cannot survive. Furthermore morphologically viable individuals that vary significantly from their parents and other conspecifics are unlikely to be ecologically viable. Natural selection ensures that most members of a population are well-fitted to their environment; the more an individual varies from the mean, the less likely they are to breed successfully, and so that outlying locus in logical space is less likely to be represented in the next generation.

Thus it is the laws of biology and biological causes that explain the clustering of individuals and so of properties. The existence of biological kinds has a natural explanation, ultimately in terms of laws. The same may well be true of natural kinds in general. When it comes to physical and chemical kinds, the laws may ensure that the clustering of properties is much more sharply defined. First, distinct individuals may share the same precise point in logical space. Two atoms can be identical. Secondly, distinct regions in logical space do exist. Thus while the mass of atoms can vary in such a way that the ranges of masses do overlap, the distinctness of regions is ensured by the fact that nuclear charge keeps the elements apart. So no gerrymandering of logical space is required to draw precise boundaries between elementary and many other chemical kinds. When it comes to more fundamental physical kinds the clustering is better defined yet, since all members of the kind (such as electrons) occupy the same point in logical space. These facts will in each case be explained by the laws of nature. Thus, while Boyd takes HPCs to be a subset of the natural kinds (they are always historical kinds—(Boyd 1999b)), it seems to me to be plausible that Boyd's homeostatic property cluster idea can be generalized to all natural kinds. Homeostatic property clusters are a specific case of 'non-accidental property clustering', where the homeostatic mechanism explains the non-accidental clustering. The kinds of physics may be called 'nomic property clusters' to indicate that the laws of nature explain in a fairly direct, non-accidental way, why certain properties cluster in fundamental particle kinds. The mechanisms and laws responsible for the non-accidental clustering will also explain the natures of those clusters—the loose and vague clusters in biology, the partially precise clusters of chemistry and the perfectly precise clusters of particle physics.

HPCs of this sort satisfy the requirements for weak realism about classification (Q1) and about kinds (Q2). Classification by HPC is natural. Not any collection of properties can form a cluster: the fact that they tend to be co-instantiated is non-accidental, explicable by natural law. The fact that the clusters are of several properties answers the kindhood question. As we saw, kinds are not essential to induction or to laws, since we can have laws and successful inductions that depend only on natural properties. However, kinds might nonetheless be an ineliminable component of science because they are an especially rich source of induction and nomic correlation—their richness ensures that they are cannot be eliminated without loss of either explanatory power or parsimony. The clustering of properties means that many properties may be inferred from the presence of just a few. For example, given that some sample is an element, measuring its melting point with sufficient accuracy is typically sufficient to identity which element it is; the same goes for a myriad of other properties, such as density, atomic weight, and so forth. And given that one knows which element it is, then one can infer all these properties, i.e. for *many* properties Φ, $Kx \leftrightarrow \Phi x$. Furthermore, there will be many other properties that will be be inferable from knowledge of the sample's kind, such as crystalline structure, Young's modulus, typical chemical properties, and so forth, i.e. properties Ψ for which $Kx \rightarrow \Psi x$ (even if not $\Psi x \rightarrow Kx$). In the biological case it will not be so common that we can infer the kind from knowledge of a single property, but very often just a few properties will permit identification of the kind; furthermore, although there will again be a rich range of properties inferable from knowledge of the kind, in many cases the inference will not be perfectly reliable. It is a pretty reliable inference that an insect has six legs, but the odd individual insect may be a mutant or have suffered an accident. So for these kinds we will typically have $N(Kx \rightarrow \Psi x)$, where 'N' is a normality or *ceteris paribus* operator.

HPCs satisfy the naturalness and kindhood requirements of natural kinds. Do they allow for strong realism, the view that natural kinds are genuine entities? The first criterion for entityhood we considered was the syntactic one—the relevant term should be a singular term employable in a true sentence; this would be demonstrated by, for example, existential generalization. Consider the following sentences: 'given a gold ring, a gold coin, and a copper coin, there is some homeostatic property cluster exemplified by the first two but not by the third' appears to be a genuine case of first order quantification. But this criterion is very weak. More robust was the idea that if it could support an essence, then something is a true entity. It is, I think, implicit in Boyd's account that HPCs provide an *alternative* to the essentialist view of natural kinds. But the appropriate contrast there is with a traditional essentialism that takes the essential properties associated with a kind to be *intrinsic* properties of the members of the kind. Darwinian population thinking shows this to be implausible with regards to biological kinds such as species (the discussion above concerning speciation provides some of the grounds for this assertion). However, just as Kripke (1980: 110–15) has emphasized the individual essences can be *extrinsic* (e.g. essentiality of origin), so likewise can kind essences (cf. Dummett 1993: 144; McGinn 1976). Consequently, essentialism can be seen to be consistent with the Darwinian view if we permit the relevant essential properties to be extrinsic properties—for example possessing a certain lineage (Griffiths 1999; Okasha 2002). And so the HPC view in particular can be reconciled with essentialism.

Consider some HPC and now allow changes to the world that would mean that the properties in this cluster no longer cluster, but some very similar set of properties do cluster. For example, consider the cluster C of properties $\{P_1, P_2, P_3, \ldots\}$ associated with some element E. Now consider another possible world, w' whether the laws differ *very slightly* from our own (e.g. because the value of some constant differs very slightly from its value in the actual world, w) so that we do not find these properties clustering, but we do find some other, similar set of properties clustering. Many of the properties in question will be quantities, so in w' we find a cluster C′ of properties $\{P'_1, P'_2, P'_3, \ldots\}$ where $P'_1 \approx P_1$, $P'_2 \approx P_2$, $P'_3 \approx P_3$, etc (i.e. for each i P'_i and P_i assign very similar values of the same quantity).

The question is whether C=C′. How should we understand HPCs and their cross-world identity conditions. Note that, for the reasons discussed above, HPCs are not supposed to be sets: it is not that HPCs *are* sets whose elements cluster. Rather, when some set of properties is such that its elements cluster, then there exists an HPC. We should think of an HPC bearing to its constituent properties something like the relation that a physical object bears to its constituent matter. Precisely *that* matter is not essential to that physical object; likewise (unlike as set of properties) precisely *those* properties need not be essential to that HPC. At a first approximation at least, we should regard the properties in C as parts of C. So we should not rule out C=C′ just on the grounds that the properties in C are not identical to those in C′. Certainly if one is a counterpart theorist as opposed to a strict cross-world identity theorist, the proposal that C′ is the counterpart in w' of C in w is highly plausible. A strict identity theorist is not required, however, to see strict identity wherever the counterpart theorist sees a counterpart relation—she may just see similarity. Can we supply cross-world identity conditions for HPCs? We should not expect that to be an easy task, given that corresponding conditions for concrete particulars, including organisms, are disputed. Nonetheless, one leading proposal for the latter maintains that origin is essential. For HPCs something similar may be correct. What explains the existence of an HPC, and what gives it the identity it does have? Note that the sorts of changes between worlds that we have been considering will leave *some* properties in a cluster unchanged. In the case of a chemical element, small changes that lead to slightly different melting points, densities, and so forth will leave atomic number unchanged; likewise such changes will leave the formulae of chemical compounds (if molecular, then ones with small molecules at least) unchanged. In the case of biological kinds it will be the relational property of line of descent that will be retained (for example, different environmental conditions might have led to the (counterpart of the) European red squirrel having different properties, such as a different coloured coat, a different size, or showing significant sexual dimorphism, but no such change could prevent the corresponding cluster from containing the property of being a rodent (or, to be more precise, being a descendent of the latest common ancestor of members of the order *Rodentia*). In these cases at least, the modally stable members of the HPCs include those properties that are explanatorily fundamental, those that explain, along with the laws, why the HPC exists at all. It is the fact that nuclear charge is explanatorily responsible for many features of atomic structure and thereby of physical and chemical properties that the chemical elements are HPCs. It is the fact of sharing a common ancestor that (in large part) explains why members of a clade tend to share genetic and phenotypic characteristics. I suggest that what explains the existence and nature of something has a good claim to fix its identity.

So the HPC view is at least consistent with strong realism, since it permits essentialism and an account of cross-world identity. We now turn to (Q4): are these kinds (a) reducible to some more general kind of entity, (b) *sui generis* but supervenient on some other species of entity, or (c) *sui generis* and a fundamental species of entity? HPC kinds are not fundamental entities. They at least supervene on the distribution of particulars and universals. Are HPC kinds a subspecies of universal?

The problem with this question is that, as we have seen, there is no agreed account of what a complex universal would be, beyond a logical combination of universals (conjunction in particular). Certainly HPCs are not conjunctions of universals, since on the conception developed so far, HPCs can survive change in (some of) the universals upon which they supervene. A better approach is to propose an account of HPCs and raise the possibility that this is one way in which a universal can be complex. My proposal is that the relationship between the properties (universals) that make up an HPC and the HPC itself is broadly analogous to the relationship between the components (basic parts) of a complex physical object and the object itself. More specifically:

- Typically, physical objects can survive (across time and across worlds) change of their parts. Likewise, as we have seen, HPCs can be constituted by different properties in different worlds. Additionally, the properties clustering to constitute biological kinds can change over time. The properties typical of a species can change over time.

- A physical object is more than just the mereological sum of its parts. Nor is mere physical proximity of the parts sufficient. Some kind of causal unity among those parts is also required. Likewise, there is more to an HPC than the mereological sum of the constituting properties; it is more also than the fact of their clustering in virtue of their being co-instantiated in many instances. Corresponding to the causal unity of a physical object is the causal mechanism or laws of nature that explain the clustering of the constituting properties.

Conceived thus, an HPC is indeed a genuine entity, whose existence supervenes on the properties and laws of nature of a world. An HPC is not a fundamental entity, (c). But we need not suppose that an HPC is reducible to the subvening properties and laws (a).

8 Conclusion

The principal lesson of this paper is that despite the attention given to the metaphysical issue of natural kind essentialism and to the status of species as individuals or kinds (or both), there remains a number of issues in the metaphysics of natural kinds that have been discussed little and are understood poorly. For example: What distinguishes, if anything, natural kinds for natural properties (the kindhood question)? Are natural kinds entities? If so, what sorts of entities? And what is the relationship between entityhood and natural kind essentialism? I have suggested some possible answers, albeit tentatively: Kinds are especially rich sources of inductive inference and non-accidental generalization. One's view of whether kinds are entities depends on one's view of essentialism. Without kinds as entities, natural kind essentialism makes no sense. At the same time, essentialism is a more robust basis for arguing for the entityhood of kinds than a purely syntactic criterion of existence. If we do accept the argument for strong realism about kinds then we have an answer to the question of what rigid designation amounts to for natural kinds (designating the same kind in all possible words). The identification of kinds with homeostatic property clusters explains why natural kinds really are kinds (and are natural). That view is also consistent with the claim that natural kinds are entities and have essences.[15]

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