PROPERTIES AND NATURAL KINDS

Abstract

How do properties and natural kinds relate? I first examine E. J . Lowe's four category ontology, which takes natural kinds and properties to compose distinct fundamental categories of entity. Having rejected this approach I look at the reduction of natural kinds to properties. I argue that natural kinds are non-accidental mereological complexes of properties.

1 Introduction

Natural kinds and natural properties are intimately related.

First, it is plausible that there is a natural property corresponding to each natural kind. Copper is a natural kind and there is a corresponding natural property: being (a sample of, composed of) copper. The red squirrel is a natural kind and it seems that there is a corresponding natural property that some animals possess: being a red squirrel.

Secondly, the possession of a natural kind seems to imply the possession of yet other properties. Things that are copper have the properties of being metallic and being able to conduct electricity. Red squirrels are mammals and eat nuts. Note that sometimes these implied properties are *necessarily* implied (necessarily copper items are also metallic), sometimes they are *contingently* and *universally* implied (all copper items conduct electricity, all red squirrels are less than five kilograms in weight) and sometimes they are *probabilistically* implied (a red squirrel probably inhabits a drey, a nest in a tree, and probably weighs less than one kilogram).

A theory of the metaphysics of natural kinds should explain these relationships between natural kinds and natural properties. It should also shed light on related questions, such as the role of natural kinds in laws of nature.

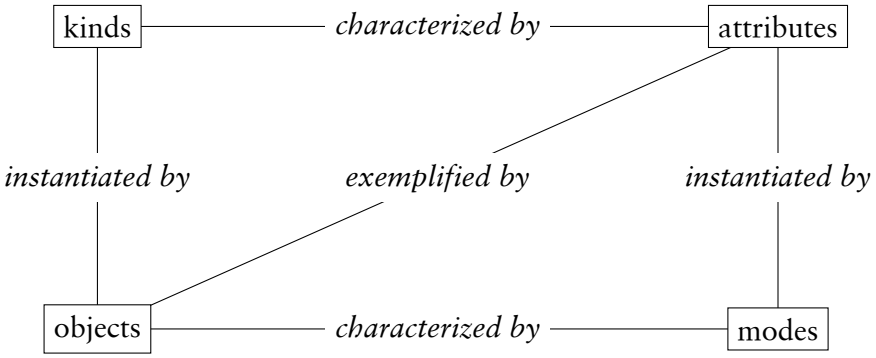

Figure 1: Lowe's Ontological Square with four categories

2 E. J. Lowe's theory of kinds and attributes

E. J. Lowe (2006) has a 'four category ontology' consisting of *individual substances* (things, objects), *property- and relation-instances* (modes, tropes), *substantial universals* (kinds), and *non-substantial universals* (attributes: properties and relations). Our interest is primarily in the third and fourth categories. Note that kinds and attributes/properties form distinct fundamental categories, although both are universals. So kinds themselves are not any type of property. Kinds and attributes stand in relationship: kinds are *characterized by* attributes. 'Copper conducts electricity' is an example of this, since the kind, copper, is characterized by the attribute, conducting electricity. Furthermore this relationship is the basic form of a law of nature. Laws of nature are the characterizations of kinds by attributes: copper conducts electricity.

Individual objects instantiate kinds, while modes instantiate attributes. The relationship between kinds and attributes—the latter characterize the former—is mirrored by the relationship between objects and modes. In a standard two category ontology of particulars (objects, things) and universals (attributes: properties, relations) there is one key relationship, usually called 'instantiation', but which Lowe calls 'exemplification'. For Lowe, exemplification is not a fundamental relationship between the fundamental categories.

Consider a red squirrel named *Cyril*. According to Lowe, the squirrel exemplifies the attribute of redness. This comes about in two ways. *First way* There is a particular mode or trope of redness, the redness of this squirrel Cyril. Cyril's redness mode is an instance of redness the attribute, and Cyril is characterized by his redness mode. So this manner of Cyril's being red involves the bottom and right hand connections in the ontological square. *Second way* Cyril belongs to the kind *Sciurus vulgaris*. Since it is in the na-

ture of the kind to be red, we can say that *S. vulgaris* is characterized by the attribute redness. (This is parallel to the fact that individual Cyril is characterized by his redness mode.) The kind (substantial universal) *S. vulgaris* is instantiated by the individual Cyril. (This is parallel to the fact that the attribute of redness is instantiated by the mode that is Cyril's redness.) This account of Cyril's redness involves the left and top sides of the square.[1]

Lowe's Ontological Square fulfils some of our requirements on an account of kinds and their relationship to properties. It articulates an account of the second of our two relations, the relation between kinds and implied properties. The implied properties are attributes (non-substantial universals, in Lowe's terminology) and characterize the kinds. And we are thereby also given an account of the basic form of a law of nature.

The Ontological Square is less helpful when it comes to understanding the relationship between kinds and their corresponding properties: copper and being (a sample of, composed of) copper. One might suppose that the relationship is also the relationship of characterization between kind and attribute, hence: Copper things are composed of copper. Or: Copper is copper. On Lowe's account that ought to be a law, but is in fact clearly a tautology.

More of a problem is the concern that we have ontological redundancy. We have both a kind *and* the corresponding property: both belong to fundamental categories; neither is reducible to the other. Surely we do not need both the kind copper and the property of being copper to be fundamental. (Of course, scientifically neither is fundamental. But the problem is the same for scientifically fundamental kinds.)

To avoid this redundancy, we can either (i) reduce the kind to the corresponding property (attribute) or (ii) reduce the corresponding property to the kind.

To take the first of these options would be to eliminate the kind category from the Ontological Square—we would be halfway to returning to the traditional two category ontology (represented by the diagonal of the Ontological Square).

To implement the second option, we can make use of Lewis's distinction between sparse and abundant properties. The latter are defined by almost any predicate. If there are any entities that are abundant properties, they are sets, and so are found at the bottom left. Whereas sparse properties are that class of properties that contains the natural properties (or perhaps just the fundamental natural properties). Sparse properties seem to demand spe-

[1] See Schneider (2009) for a careful articulation of the Ontological Square.

cial ontological treatment—it is these that are the attributes (non-substantial universals) in the Ontological Square. The proposal is, then, that 'being composed of copper' is not a sparse property but an abundant one. There is therefore no attribute of being composed of copper. This would appear to resolve both the aforementioned problems. Since there is no attribute of being composed of copper, there is no worry about 'copper things are composed of copper' being a law of nature. And we do not have any redundancy, since the kind copper can do all the work.

This, however, will not do, because we need some corresponding properties to be attributes, and so to be sparse. Take the kind mammal. There is a corresponding property, being a mammal (or: being mammalian). According to the proposal of the last paragraph, this is not a sparse property. However, consider: red squirrels are mammals (or: the red squirrel is a mammal). We already saw that this is an example of the top line of the Ontological Square, the characterization of a kind by an attribute. So for this law, or law-like truth, we do need the property of being a mammal to be an attribute and so sparse, not abundant.

So the problem of redundancy returns—Lowe's system seems to require us, at least in some cases, to have both the kind and its corresponding property as distinct and equally fundamental entities. There are also further problems with Lowe's account of the laws of nature. While it seems to work for laws and lawlike statements such as 'copper conducts electricity' and 'red squirrels are mammals', it has difficulty with laws, such as the many laws of physics, that relate quantities, which are best understood as attributes, not as kinds (Bird 2011).

3 Kinds as properties

I propose that the relationship between kinds and properties should not be seen as a relationship between entities of distinct categories. In at least some cases the properties corresponding to a kind must be sparse, natural properties. . To avoid one or other of the kind and the corresponding kind property being a redundant entity, we should therefore get rid of the kind as a distinct and independent entity. This need not be eliminativism about kinds (especially as eliminativism does not sit well with essentialism about kinds). Rather kinds must just be properties. So, for example, we do not need both the kind copper and the property being copper as distinct and independent entities; there is just the property of being copper.

Now we have an answer to our first question about the relationship between kinds and properties, that concerning corresponding kind properties. Kinds just *are* their corresponding kind properties. But we now do not have an answer (yet) to the question about the relationship between a kind and its implied properties. One might simply say that these are laws or lawlike relationships and therefore that the question should be answered by our best account of laws and lawlikeness. I think, however, that we can do better.

We should first note that while mereology is typically applied to objects, there is no reason why it should not be applied also to properties, if those properties are genuine entities. Let us take it as given that natural properties are universals. Then given two universals, A and B, we can consider their sum or fusion, A+B. Let us say that there is such an entity and that it too is a universal. When it is present in some instance it is wholly present (that is the nature of universals) and so both A and B are present in that instance. So anything that instantiates the universal A+B also instantiates A and instantiates B. The fusion of two universals thus corresponds to the logical conjunction of the predicates denoting the universals (Hawley and Bird 2011).

If we reject both nihilism and universalism but accept special composition regarding sums of universals, then in some possible cases of sums there really are entities that are the fusions of the constituent universals. These are genuine, complex universals that have simpler universals as parts. Since we adopt special composition, there should be some principle that distinguishes the cases where universals do fuse to form a complex universal and those cases where they do not (van Inwagen 1990).

What exactly a principle of special composition should be is controversial. Nonetheless it is plausible that a principle of composition should reflect coherence among the parts of an object. That is, facts about one part should have implications regarding facts about some other parts. In a simple physical object, such as a pebble, facts about the location of one part have implications about the locations of other parts of the pebble. Whereas the sum of the pebble and the Eiffel Tower lacks such coherence, since facts about one part of the stone have no implications for any parts of the Eiffel Tower. This, I think, is the appeal of the 'fastenation' view of the composition of physical objects (van Inwagen 1990; Markosian 1998). In the case of universals then, coherence is a matter of correlations between them. For example, the possession of one universal by some object might imply the possession of some other universal. Or a set of universals might together imply the possession of several others. The implication might be probabilistic, so the possession of some universals makes the possession of other universals probable. So we can say that a set of universals is highly coherent when there are many

highly probable implications among subsets of the set. Highly coherent sets of universals do fuse to form a new universal.

3.1 Fundamental kinds

Let us consider an example. The electron is a fundamental particle. Three properties are necessary and jointly sufficient to characterise the electron: unit negative elementary charge ($q_e = -1.6\times10^{-19}$kg) C , mass of 1/1,823 daltons ($m_e = 9.11\times10^{-31}$kg), and spin 1/2 (s). There is a universal that is the fusion of the universals that are these three properties. We do not need a fourth property, being an electron, distinct from these. The property, being an electron, just is the fusion of these three properties. This fusion is instantiated in every electron, and so every electron also instantiates the parts of that fusion, *viz.* the universals of having unit negative elementary charge, having mass of 1/1823 daltons, and having spin 1/2.

Given restricted composition, why should we think that there is such a universal as this fusion? But not say, a fusion of the universals unit negative elementary charge, mass of 1/1,957 daltons, and spin 1/2—that is, a fusion of the same charge and spin universals but a different mass universal?[2]

For a start, there are lots of things instantiating the first combination of universals (all the electrons) but none instantiating the second combination. We can say more. Consider the determinable property, having negative charge, and let us assume that it is a universal. That something has this property raises the probability that it is an electron, but not by a great deal, since many things other than electrons are negatively charged. That is having the negative charge universal does not raise the probability of having the mass of 1/1,823 daltons universal or the spin 1/2 universal to a significant value. On the other hand, that something has unit negative elementary charge makes it quite likely that it is an electron, since four kinds of entity—the three leptons (electron, muon, and tau), and the W^- boson—have unit negative elementary charge. These particles have different masses, but the three leptons do all have spin 1/2. So that something instantiates the unit negative elementary charge universal raises the probability that it instantiates the mass of 1/1,823 daltons universal to quite a high value and raises the probability that it instantiates the spin 1/2 universal to a higher value still. If something instantiates both the unit negative elementary charge universal and the mass of 1/1,823 daltons universal, then it is certain that it also instantiates the spin 1/2 uni-

[2]There is such a mass universal, it is the mass of the charm quark.

versal. Likewise, instantiating the mass of 1/1,823 daltons universal and the spin 1/2 universal raises to close to 1 the probability that it instantiates the unit negative elementary charge universal.[3] (I will discuss these probabilities in more detail later.)

While q_e, m_e, and s are essential properties of the electron, in general the properties fusing to form the property complex that is a natural kind may include accidental and contingent properties. One should not subscribe to mereological essentialism—a complex entity may have different parts in a different possible world.

In the case of the electron, it is unclear whether it possesses any sparse properties other than those essential ones just mentioned. For example, the magnetic moment of an electron is an important quantity. But its value is determined exactly by the essential properties plus the laws of nature. One might not regard it then as an additional property, especially if one thinks that the laws of nature are metaphysically necessary. On the other hand, if one thinks that the laws are contingent, one might be inclined to regard the magnetic moment as an additional sparse property, a further part of the complex of universals that is the electron kind.

We can understand any natural kind as a complex that has sparse properties, universals, as its parts, including chemical and biological kinds (Hawley and Bird 2011). In such cases those properties are not fundamental properties. That, however, is not inconsistent with their existence. For as we have seen, there are non-fundamental sparse properties that are universals—the electron kind is an example. That example is a case of a complex non-fundamental sparse property. Are there simple non-fundamental sparse properties? That is unclear, but if there are emergent properties, they might be candidates.

3.2 Biological kinds

Now let us now consider the kind, the red squirrel, *S. vulgaris*. This has many implied properties: the red squirrel is a mammal, it has a red coat with a cream or white underside. The red squirrel eats seeds and nuts, which it will also bury in caches. Red squirrels inhabit dreys and are non-territorial. If we were to assume that these properties are sparse properties and so universals,

[3] Close to 1 because positrons also have mass of 1/1,823 daltons and spin 1/2 but have *positive* elementary charge. As far as we are aware they are much rarer than electrons.

then one might take the kind, *S. vulgaris*, to be the fusion of these (and other) properties.

That, however, would not be quite right. For not all red squirrels have red coats—some will have grey coats in winter. Clearly, they are not always eating nuts and seeds. And so on. So the properties in question are typically dispositional properties. A red squirrel is disposed to have a red coat in certain conditions and is disposed to eat seeds and nuts, and so on.

All squirrels are actually mammalian, not just dispositionally so. If we understand 'mammalian' as 'belonging to the class *Mammalia*', then this property, though essential to the kind *S. vulgaris*, is an extrinsic property of the squirrel. Biological taxa, for sexually reproducing organisms, are understood as clades, that is as kinds based on shared lineage. So the view I am proposing demands that some universals are extrinsic properties.

3.3 Structural kinds

I now consider a third kind of case, concerning those kinds where the structural relations among the parts are essential. Methane is (essentially) the compound CH_4—that is, a sample of methane is made up of molecules of four hydrogen atoms bonded to a single carbon atom. It is natural then to think that the methane universal is related somehow to the (probably complex) universals *being a carbon atom* and *being a hydrogen atom*. Could this relation also be parthood, as in the previous cases? If so, that would explain, as before, why wherever *being a methane molecule* is instantiated, so are *being a carbon atom* and *being a hydrogen atom*.

Lewis (1986), however, rejects this idea on the ground that the combination of these universals does not uniquely determine the complex universal to be methane. Exactly the same universals will be present in other hydrocarbon kinds—ethane, propane, butane, pentane, and so on. One might therefore add a further universal *having parts arranged tetrahedrally*. But even this will not be enough. Consider the compounds, chloromethane, dichloromethane, and trichloromethane. These all contain carbon, hydrogen, and chlorine arranged tetrahedrally, but are different kinds.

Nonetheless, one does not have to subscribe to uniqueness of composition (Hawley 2010; Hawley and Bird 2011). After all, the same lump of clay can compose many different objects. Likewise, there could be distinct complex universals composed of the same simple universals.

If one were to demand uniqueness of composition, this is available anyway. The view I propose will include the implied natural properties in the complex universal, such as boiling points, density, characteristic chemical re-

actions and such like. And these will distinguish between the different compounds with the same chemical constituents.

3.4 The coherence of universals

Above I said that entities, including universals, might fuse when they have what I called 'coherence'. Coherence enables one to make inferences about the parts from the whole and about the whole from the parts, and hence from some parts to other parts. In the case of a physical object, knowing where one part is located, for example, enables one to infer, at least roughly, where the other parts of the object are. This idea needs some fleshing out, in particular as it applies to universals.

First, this coherence should be non-accidental. Two properties might in fact be perfectly correlated in the actual world, but this is a mere coincidence. While one is in fact able to infer the presence of the one from the other, these inferences have no modal robustness. In very nearby worlds this correlation breaks down. In such a case there is no complex universal with these as parts. The rejection of such a complex universal is analogous to rejecting the claims of the contact view of composition for physical objects. Fastenation, the view that the parts of a physical object are fastened together, provides some degree of modal robustness—if two things are fastened together, then changes in location of one part will typically mean changes in location to the other part. So, for two universals to fuse to form a conjunctive universal, their correlation, which need not be perfect, must nonetheless be non-accidental.

For example, in the case of the electron, that something possesses one of the essential properties raises the probability that it possesses the others. This is non-accidental and is a consequence of the laws of quantum mechanics that underlie the standard model of particle physics.

Secondly, the complex universals that are kinds should have boundaries. By a boundary, I mean that there should be (relatively) many things having the possessing the properties in the complex but fewer things possessing a set of nearby properties (in the actual and nearby possible worlds). For example, we can plot a histogram of the masses of the nuclei of atoms. These will fall into neat columns separated by a gap, each column corresponding to an isotope. While some theorists claim that natural kinds require sharp boundaries like this (Ellis 2001), that does not seem necessary. There can be intermediate cases between kinds, so long as these tend to be fewer in number than exemplary members of the kind. There are gaps between kinds, but these are not empty. In our histogram, they are troughs. This is what we will find if

we plot a histogram for properties of members of the squirrel genus *Sciurus* against properties such as body mass, coat colouring, and so on.

Putting these two together, we can expect universals to cohere when, for non-accidental reasons, objects will tend to instantiate those universals rather than nearby sets of similar properties. The instantiation of some subset of these cohering universals will make it likely that an object instantiates all the cohering universals, and rather more likely than that the object instantiates some similar but non-cohering set of universals. This cohering of universals I take to be the correlate of Boyd's clustering of properties (Boyd 1999). The homeostatic processes underlying the clustering of properties in biological kinds I take to be one of the non-accidental reasons why we find the individuals distributing in the uneven way and so why some sets of properties cohere, but others do not.

Just as the homeostatic property cluster view of kinds is consistent with both essentialism and its negation, this view of kinds, as complex universals allows for essentialism but does not require it. It does not require it because the same complex universal may be made up of an entirely distinct (though typically very similar) set of universals in another possible worlds. We should reject mereological essentialism for universals as well as for particulars. Nonetheless, it could be that some members of the compounded set of universals are essential to the compound, just as a having a part that is a cutting blade is essential to a penknife, even though it may or may not have parts that are other tools (bottle opener, hoof pick etc.). Such properties will be those that are responsible for the cohesion of the universals. That a copper atom has 29 protons in its nucleus explains why copper has the other properties it does have. Without that universal, having atomic number 29, the other universals in the complex universal that is copper would not cohere.

4 Conclusion

Natural kinds and natural properties are indeed intimately related: natural kinds *are* natural properties. They are complex natural properties (universals) composed of simpler properties, just as familiar physical objects are composed of simpler physical objects. Because universals are fully present wherever they are instantiated, whenever a natural kind is present, so are all its component properties, some of which may be dispositional. All things instantiating the kind copper thereby instantiate its component properties, such as being metallic, conducting electricity, being red in colour, and so on.

When do simpler universals combine to form a natural kind? When they have sufficient coherence, which is to say that the presence of some of the properties implies or makes probable the presence of others. Coherence is vague, so it can be indeterminate whether a set of properties composes a natural kind. But physical objects are vague in this respect also.

This account of natural kinds answers our initial questions about the relationship between natural kinds and properties: how it is that a natural kind relates to its corresponding natural property (identity) and how it relates to its implied properties (whole to part). It fits with the homeostatic property cluster account of natural kinds also accommodates but does not require essentialism about natural kinds.

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