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ARTICLE

How Scientific Is Scientific Essentialism?

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Abstract Scientific essentialism holds that: (1) each scientific kind is associated with the same set of properties in every possible world; and (2) every individual member of a scientific kind belongs to that kind in every possible world in which it exists. Recently, Ellis (Scientific essentialism, 2001; The philosophy of nature 2002) has provided the most sustained defense of scientific essentialism, though he does not clearly distinguish these two claims. In this paper, I argue that both claims face a number of formidable difficulties. The necessities of scientific essentialism are not adequately distinguished from semantic necessities, they have not been shown to be necessities in the strictest sense, they must be relativized to context, and they must either be confined to a subset of scientific properties without warrant or their connection to causal powers must be revoked. Moreover, upon closer examination (1) turns out to be a trivial thesis that can be satisfied by non-kinds, and (2) is inapplicable to some of the most fundamental kinds in the basic sciences.

Keywords Essence · Essentialism · Science · Natural kinds · B. Ellis

1 Introduction

Though it has not always been labeled as such, "scientific essentialism" has been a popular position among philosophers since the work of Kripke (1972/1980) and Putnam (1975). Both Kripke and Putnam used thought experiments involving possible worlds to suggest that some general terms, like individual proper names, are rigid designators. The thesis that a proper name is a rigid designator is fairly straightforward and amounts to the claim that it picks out the same entity in every possible world in which that entity exists. However, the extension of this notion to general terms is not so clear. It cannot be taken to mean that a rigid general term picks out the same set of entities in every possible world, since very few, if any, general terms would seem to satisfy this condition, and certainly not the ones commonly associated with essences (the term 'tiger' would surely pick out a different set

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of creatures in another possible world). Instead, there seem to be two proposals for how this notion can be extended to general terms, both of which involve an essentialist claim of some kind. The first is to say that a general term *G* is rigid just in case it picks out the same property or set of properties in every possible world. The second way to understand the notion of rigid designation as applied to general terms is to say that a general term *G* designates rigidly just in case for every individual *i*, if *G* applies to *i* in the actual world then *G* applies to *i* in every possible world in which *i* exists. Corresponding to these two construals of rigid designation, are two essentialist theses, which are not always clearly distinguished by essentialists and their critics. They may be formulated as follows:

> Essentialism about kinds (EK): In every possible world, kind *K* is associated with the same set of properties $\{P_1, \ldots, P_n\}$.
> Essentialism about individual membership in kinds (EM): Every individual member *i* of kind *K* belongs to *K* in every possible world in which that individual exists.

Although (EK) appears to be independent of (EM), a case can be made for the claim that (EM) presupposes (EK). It seems difficult to maintain essentialism about kind membership without being an essentialist about kinds themselves. Unless kind *K* has some essential properties, the claim that an individual is essentially a member of *K* would appear to be vacuous. Therefore, I take it that (EM) presupposes (EK), but the converse does not appear to be the case.

Scientific essentialism holds that the above theses apply to scientific kinds, or at least some scientific kinds. The main argument or family of arguments in support of the first essentialist thesis is commonly thought to be based on the Twin Earth thought experiments developed by Putnam. Typically, we are asked to consider another possible world just like this one in every respect except that the substance that fills the oceans, quenches thirst, falls from the clouds, and so on, is not composed of H_2O, as on earth, but has some other chemical composition, XYZ. Since, the argument goes, we are intuitively reluctant to consider that this substance is water, and since we would reserve the term 'water' exclusively for substances that are composed of H_2O, in this world as in every possible world, this shows that water is necessarily composed of H_2O, which seems to support EK. This argument and these intuitions have been the subject of a great deal of philosophical analysis, and I will not attempt to summarize the debate here. In this paper, I intend to bracket this argument for two reasons. First, while the intuitions that it elicits are widely shared, they are by no means universal and have been challenged on a number of counts. Second, whatever the status of the argument, it is geared mainly towards the use of natural kind terms in the vernacular, rather than the use of scientific terms. What we would or would not say when it comes to our ordinary word 'water' is not directly transferable to our use of general terms in scientific discourse. If scientific essentialism is to be justified as a philosophy of science, its metaphysical claims need to be squared with the aims and practices of science.

Recently, scientific essentialism has received perhaps its most sustained defense in two works by Ellis (2001, 2002). Ellis claims that scientific essentialism is ultimately justified by according better with science in a general way and that it is the best "metaphysic" for science. However, I will argue that essentialism encounters some fundamental problems which constitute obstacles to integration with science and a naturalized account of scientific inquiry. In what follows, I will raise a number of foundational problems for the two essentialist theses identified above as applied to science, problems which I take to present serious obstacles to accepting essentialism about scientific kinds. Some of these problems will be relevant to EK, others to EM, and yet others to both. Throughout, I will be concerned to show that essentialism does not provide an adequate metaphysical basis for science, either because some of its central claims are inadequately supported or because they are out of keeping with some aspects of science as we know it.[1]

2 Metaphysical and Semantic Necessity

Advocates of scientific essentialism insist that theirs is a thesis of metaphysical rather than semantic necessity. They maintain that when it comes to EK, attributions of essences to scientific kinds do not (merely) concern the terms used to identify those kinds, but rather the kinds themselves.[2] The essences they are concerned with are supposed to be explanatory and discoverable a posteriori by science, rather than merely nominal or stipulative. For example, it is part of the essence of electrons to have a negative charge of 1.60×10^{-19} C, and that is a fact about electrons rather than one about how we choose to apply the term ‘electron’. Such claims have been contested by critics of essentialism, who have challenged essentialists to show that the claim that electrons necessarily possess certain properties is a claim about electrons themselves.[3] Some of these critics charge that no amount of empirical investigation of electrons could possibly ground a claim of necessity, since all that such an inquiry could uncover would be facts about how electrons actually are, not how they are necessarily. But Ellis has an indirect way of arguing that the necessities that he is interested in are grounded in the natures of things rather than the way we use language.

Ellis puts forward two arguments for the claim that his essentialist theses about electrons (among many other kinds) are a matter of metaphysical rather than semantic necessity. His first argument is that if someone does not know that all electrons are negatively charged that does not show that he does not know what electrons are (Ellis 2001, pp. 34–35). He contrasts this with a standard case of analyticity, such as the purported fact that all bachelors are unmarried men. In that case, someone who does not know that all bachelors are unmarried men does not know what a bachelor is. In other words, Ellis thinks that it is a mark of semantic necessity that not knowing the definiens is tantamount to not knowing what the definiendum is, whereas that is not the case for metaphysical necessity. But notice that in the bachelor case, Ellis imagines a case in which someone does not know the entire definition, while in the electron case, he merely imagines a case in which someone fails to know one of the tenets of the purported definition. Ellis does not think that having negative charge is the only essential property of electrons; he also claims that electrons necessarily have all their intrinsic properties: charge magnitude, mass, spin angular momentum, and so on. Therefore, to see whether this argument is sound, we need to expand the purported definition of ‘electron’ so that it includes not just the property of being negatively charged but other allegedly essential properties of electrons, namely: “An electron is

[1] In addition to Ellis, other recent expressions of scientific essentialism can be found in Bealer (1987, 1994), and Bird (2001). But I will concentrate on Ellis’ version, since it is the most sustained presentation of the position.

[2] Does this also apply to essentialism about kind membership (EM)? Since individual scientific entities are rarely given proper names, it seems harder to assess this claim when it comes to EM than to EK.

[3] Consider Mackie (1974, p. 560) on necessities involving individual persons and natural kinds: “Though these necessities apply to individual things and natural kinds (‘This man could not have…,’ ‘Gold could not have…,’ etc.), that they so apply is primarily a feature of the way we think and speak, of how we handle identity in association with counterfactual possibility.”

an elementary particle with a negative charge of 1.6×10^{-19} C, a mass of…" Now if someone does not know *any part* of this definition, it is not clear on what grounds one would maintain that that person knows what an electron is. As in the bachelor case, someone who knows no part of this definition arguably does not know what an electron is.

It might be thought that Ellis is being interpreted uncharitably. He states that when it comes to metaphysical necessity, one need not know the definition to know the definiendum, whereas the same is not true for semantic necessity. One way of reading this claim is to interpret it as saying that one need not know *any part* of the definition in the case of metaphysical necessity, whereas one needs to know at least part of the definition in the case of semantic necessity. That is how I took it above. But there is another interpretation: one needs to know only part of the definition in the case of metaphysical necessity, but one needs to know the entire definition for semantic necessity. But this can also be shown to be false. In at least some cases of semantic necessity, we judge that someone knows what the definiendum is even if he does not know the entire definition (or even any part of it). Take the concept of a *circle*, which is defined as a set of points equidistant from a given point, the center. Someone could be said to know what a circle is without knowing the definition of 'circle'. Yet, this is a paradigmatic case of semantic not metaphysical necessity, which means that one cannot distinguish the two varieties of necessity in the manner suggested. Of course, it could be that whether or not someone can be said to know what x is, depends to some extent and in some contexts on whether that person knows the definition of 'x' (in whole or in part), but our judgments in this regard do not seem to be correlated with the contrast between alleged metaphysical and semantic necessities.

Ellis may respond to these objections by saying that metaphysical necessities have nothing to do with "definitions" at all. Instead of attempting to distinguish metaphysical necessities from semantic ones by distinguishing what needs to be known in each case in order to be said to know the definiendum, he might say that in the case of metaphysical necessities there are no definitions to be had in the first place. In order to support his case that there can be no metaphysically grounded definitions, Ellis (2001, p. 35) considers all the known essential properties of electrons, P_1, P_2, …, P_n, and asks whether they could not be used *jointly* to provide a definition of electrons. He makes two points in response. First, he claims that such a "real definition" would be corrigible in the way that a mere "nominal definition" is not. Second, and presumably relatedly, a "real definition" is open-ended, while nominal definitions are not. Again, focusing on a term like 'bachelor' may make the contrast between the two cases seem greater than it is. But consider a closely related purportedly analytic statement such as, 'Marriage is a contract involving a long-term commitment between one man and one woman'. Social and juridical developments in the past couple of decades have shown that a statement which may once have been regarded as analytic is in fact corrigible in a way that might not have been anticipated. The definition may now be revised to include contracts between two men or between two women. As for the open-endedness of metaphysical as opposed to semantic necessities, this too can be challenged on similar grounds. Not only is a definition like this one corrigible, it is open-ended in the sense that there seem to be no limits to the number of revisions that might be necessitated in the definition by future developments.

Ellis' second argument for distinguishing metaphysical necessity from semantic necessity has to do with the grounds upon which such claims are made. He writes that "the main reason for distinguishing between a metaphysically necessary proposition and an ordinary analytic one is that the ground of the former is radically non-linguistic and objective, while that of the latter is not." (2001, p. 36) As it stands, this seems to beg the question, since whether or not the grounds of the necessity are linguistic or not is precisely what is at issue. But Ellis elaborates on this by saying that even if we did not have a name for electrons they would still be negatively charged, but the same cannot be said for bachelors being unmarried men. However, to the extent that this claim is true, it is just an artifact of the particular example he has chosen, which pertains to human social arrangements. Consider a different instance of semantic necessity: 'A rectangle is a four-sided plane figure with four right angles.' In this case, it is clear that rectangles would still be four-sided plane figures with four right angles whether or not we had a name for them. Ellis then goes on to say that the distinction between bachelors and other men depends on relations between people and that these are by nature accidental relations. By contrast, the fact that electrons have spin ½ is intrinsic. But neither point is applicable to the proposition that a rectangle is a four-sided plane figure with four right angles, since that does not involve an accidental relation and it predicates an intrinsic property of rectangles.[4] Generally, there is no reason to believe that all cases of purported semantic necessity involve accidental relations or are non-intrinsic.

My aim in undermining the contrast that Ellis draws between semantic and metaphysical necessity is not to try to show that all such necessities are in fact semantic ones. Rather, the point is that he has not succeeded in distinguishing the metaphysical necessities of the scientific essentialist from mere semantic necessities or analytic statements. He writes: "The necessity of the metaphysically necessary proposition thus depends on what exists in nature, whereas the necessity of the analytic proposition depends on our social practices and linguistic conventions" (2001, p. 37). But he has given us no way of differentiating the necessities of the scientific essentialist, which are supposed to pertain to the deep structure of reality, from mere semantic conventions. Still, scientific essentialists may protest that even though there may be no ready way of distinguishing their metaphysical necessities from semantic necessities that does not show that they are not, for all that, distinct. They may say that our lack of a criterion to differentiate the two does not mean that there is no difference between them. The problem with this response is that essentialists like Ellis are clearly concerned to show that we can tell the difference between the two types of necessity, and justify the claim of distinctness by putting forward criteria by which they can be distinguished. That is, they rest their claim of distinctness on their ability to tell apart semantic and metaphysical necessities. In the absence of some other argument that these two types of necessity are genuinely different, all we have are the criteria discussed and dismissed above. Thus, the onus is on the essentialist to show that metaphysical necessities concerning science are genuinely different from analytic statements. Notice that we cannot distinguish the two types of necessity by adverting to subject matter. That is, we cannot say, for example, that the metaphysical necessities of the scientific essentialist pertain to the natural world, while semantic necessities concern either logical or mathematical truths, or else terms derived from human or social phenomena. There are some semantic necessities that clearly pertain to natural phenomena. For instance, the statements, 'All neutrons are nucleons' and 'All viviparous organisms produce live offspring,' would seem to be semantic necessities rather than metaphysical ones.

[4] Here, we need to be careful not to confuse essentialism about kinds (EK) with essentialism about kind membership (EM). It may be accidental of some figure that it is rectangular; in some other possible world it may have been square. But it is surely not accidental to the kind *rectangle* that it is associated with the property of being a four-sided plane figure. That is presumably true in every possible world in which the kind *rectangle* is exemplified.

In arguing that Ellis has not succeeded in distinguishing metaphysical necessities from statements held constant by semantic convention, I am not committed to the position that there are such things as incorrigible semantic conventions. Nor am I committed to saying that one can prise apart the semantic component from the factual component of scientific statements in general. Rather, I have argued that scientific essentialists need to demonstrate that the purported metaphysical necessities of scientific essentialism are not mere analytic statements, which depend on semantic conventions.[5]

3 Absolute Necessity

Another difficulty with scientific essentialism has to do with the claim that a posteriori necessities such as those found in statements of natural law are absolutely necessary, that is necessary in every possible world without exception. Moreover, the natural laws are said to be immanent in the causal powers or dispositions of natural substances. For example, scientific essentialists like Ellis hold that electrons necessarily have negative charge and that this claim is "really" or "absolutely" necessary, in the sense that it holds in every possible world. It is not just physically or naturally necessary, true in every possible world that happens to share our physical or natural laws (which is perhaps a more intuitive view). Ellis (2001, p. 234) is forthright in asserting that his brand of essentialism regards statements concerning scientific essences to be necessary in the strictest possible sense. They are true in every possible world, not merely every physically possible world. This claim of absolute necessity is usually made with regard to EK rather than EM. But if the claim holds with respect to kinds themselves, then it would appear to follow also for kind membership—provided we do not have some other reason for denying essentialism about kind membership. That is, if electrons have certain properties in every possible world in an absolute sense, then we would expect every particular electron to be an electron in every possible world without exception, not just those that share our natural laws (but see Sect. 6 for an argument that renders this point moot). There is supposed to be an important difference between the claim that the natural laws are contingent and could have been otherwise and the essentialist claim that they are absolutely necessary, true in every possible world without exception. But I will argue in this section that the claim that EK holds with absolute necessity cannot be upheld.

The essentialist claim may appear somewhat surprising, since it rules out possible worlds in which electrons are, say, positively charged or neutral. Perhaps more surprisingly, if we allow that electrons have all their intrinsic properties essentially, this rules out worlds in which the magnitude of the negative charge on an electron is ½ e or 2 e or even 1.0001 e, or worlds in which electrons have a mass negligibly greater or smaller than their actual mass, or worlds in which electrons have spin 1 or −½, and so on.[6] To the objection that one could surely imagine electrons to be slightly different than they actually are, Ellis responds by saying that, "Conceivability is not a good test for real possibility" (2001, p. 54), and "Imaginability is a very bad test of possibility" (2001, p. 232).

[5] See Nozick (2001, p. 133) for a catalogue of alleged metaphysical necessities that have been abandoned in light of further empirical investigation.

[6] Needless to say, essentialists do not rule out the possibility that we might come to discover, for example that the mass of the electron is larger or smaller than we thought, but that is an epistemic rather than a metaphysical possibility. Given that it actually has the mass m_e, it does so necessarily.

To say that electrons are necessarily negatively charged is to say that they are negatively charged in every possible world in which they exist. Obviously, they cannot be negatively charged in a world in which they do not even exist. Thus, the existential proviso, "in every possible world in which electrons exist," is used to qualify any essentialist claim about electrons. Another way of expressing the essentialist position is by saying that, if electrons exist, then they have negative charge e; otherwise they do not exist. But it is also the case that there are many worlds (indeed the vast majority of possible worlds, to put it crudely) in which electrons do not exist. Thus, the essentialist must allow the possibility of worlds in which electrons do not exist but other particles exist that are exactly like electrons in every respect but have charge ½ e. Even if we accept Ellis' claim about the unreliability of our imaginations when it comes to possible ways that electrons could have been, all bets are off in worlds in which electrons do not exist. There can be no essentialist obstacle to saying that there may be a world in which there are no electrons but particles just like electrons in every respect except that they have a mass that is negligibly larger than that of electrons.[7]

This point about scientific essentialism has been made before. Using the example of the gravitational force, Levin (1987, p. 290) writes that, according to essentialism: "A world in which objects follow an inverse-square attractive law with a different coupling constant would have been, if one can put it this way, a world lacking the gravitational constant; it would not have been a world with a different gravitational constant." But he goes on to add that it is entirely consistent with this doctrine that "there could have been a force *other than gravity* acting between bodies. There could have been an inverse-square force with a different coupling constant, or a force satisfying a function of a different form altogether" (1987, p. 291; original emphasis). Ellis responds to Levin's claim as follows:

> But how does Levin know that objects "might" have tended to accelerate toward each other as the inverse cube of the distance? Is it not precisely because he thinks that the laws describing the dispositions of objects to accelerate towards each other, which the law of gravity was postulated to explain, are contingent? If so, then he begs the question against any essentialist who would say that these laws are also necessary. (2001, p. 257n.2)

Here, Ellis seems to be saying that the only reason for thinking that there could be something that obeyed the inverse-cube law rather than the inverse-square law is the supposition that the law of gravity is contingent. This appears to leave us with a standoff between those who assert that the law of gravity is contingent and those, like Ellis, who deny it. However, scientific essentialists have no grounds for denying that there might have been *another force* in existence that did obey an inverse-cube law. Given the "existential proviso" mentioned above, the essentialist cannot dismiss the possibility of a world in which an inverse-cube force replaces the force of gravity. Elsewhere, Ellis concedes that "there might be worlds in which these [essential] properties are not instantiated, or in which there are dispositional properties of other kinds" (2001, p. 48). This confirms the observation that essentialists do not have a way of ruling out a world in which gravity is replaced by a *different force*, as a result of which massive objects are disposed to accelerate towards each other at a rate that is inversely proportional to the cube of the distance between them.

[7] A referee points out that this is in keeping with the premise of Putnam's original Twin Earth thought experiment. On Twin Earth, there is no water (i.e. substance with microstructure H_2O), but rather a substance sharing many of water's macroproperties.

Ellis might object to this conclusion by saying not only that gravity necessarily obeys an inverse-square law but that any law describing the dispositions of massive objects to accelerate towards each other would necessarily have the same form as the gravitational force. But he could only maintain this if he also believes that any such force that had a form that is different from the gravitational force would not be a force between *massive objects*. According to this way of thinking, if an inverse-cube force were to obtain, it would not be a gravitational force, but also: mass would not be mass, acceleration would not be acceleration, distance would not be distance, and so on. In other words, all the quantities involved in the formulation of the law of gravity would necessarily be different if one of them were different.[8] But whatever the intuitive merits of this claim, it would lead anti-essentialists simply to reconstrue their claims in terms of surrogates for mass, acceleration, and so on, as in the original case involving electrons. It is again open to them to redescribe the possible world in such a way as to avoid use of the relevant terms, and there seems to be nothing in the essentialist repertoire that would prevent them from doing so. Thus, they would reaffirm their belief in the possibility of a world in which a force of schmavity caused schmassive objects to schmaccelerate towards each other at a rate that is inversely proportional to the cube of the schmistance between them. Despite the fact that they are using terms not found in any physics textbook, we all know what kind of world they are describing.

To recapitulate, scientific essentialists hold that gravity could not have obeyed an inverse-cube law, but some of their opponents respond by saying that it could have. When essentialists insist that this would not be *gravity*, anti-essentialists can rephrase their claim by saying that there might have been a force just like gravity but for the fact that it accelerates masses in accordance with an inverse-cube law. Essentialists may then say that these would not be *masses* and this would not be *acceleration*. Their opponents can again rephrase their claims using other terms. But I contend that the use of different terms does not make a substantive difference to the anti-essentialist claim. The possible world that anti-essentialists describe is a mere notational variant of the one that scientific essentialists deem to be impossible. The upshot of this discussion is that, upon examination, there does not appear to be any real substance to the essentialist thesis that natural laws are necessary in the strictest or absolute sense. It does not rule out the possibilities that it appears to rule out.

At this point, essentialists might object that the anti-essentialist redescription of the inverse-cube world is not merely a notational variant of a world they consider impossible. Essentialists insist that it is crucial to their view that the force imagined by the anti-essentialists would not, for all that, be *gravity* (and so on for the other quantities involved). But it is not clear how they would go on to justify this claim. Ellis might argue that this is a fact about gravity, rather than a mere convention regarding the use of the term 'gravity'. But I have already argued in the previous section that he has not given us a means for distinguishing purported metaphysical necessities from semantic conventions. In the absence of a guarantee that all features of the gravitational force are indeed essential to it, and that this is a brute metaphysical fact about gravity rather than a mere convention

[8] This is suggested, for example, by Fine (2002/2005, p. 239), when he writes: "However, ever since Kripke (1980), we have learnt to be suspicious of such considerations (e.g. that bodies should attract one another according to an inverse cube law). For can we be sure that the hypothetical situation in which an inverse cube law is envisaged to hold is one in which the bodies genuinely have mass? Perhaps they have some other property somewhat like mass, call it schmass, which conforms to an inverse cube law." But Fine's view, unlike Ellis', distinguishes natural necessity from metaphysical necessity; he regards some but not all natural laws as being metaphysically necessary.

governing the use of the term 'gravity', it does not seem possible to maintain that the necessities of the scientific essentialist are absolute necessities in the requisite way.

4 Essence, Accident, and Incident

The traditional distinction between essential properties and accidental ones is supposed to be clearly defined and context-independent. Essential properties are had necessarily by their bearers, cannot be lost or acquired (without altering the identity of the things that bear them), are shared by all members of a kind, and make things the kinds of things they are. By contrast, accidental properties are contingent rather than necessary, may be lost or acquired (without an alteration in identity), are not necessarily shared by all members of a kind, and do not characterize the kinds to which things belong. In either case, whether a property is had essentially or accidentally is supposed to be a fact about the property's bearer, which does not depend on its spatio-temporal location, the observer's perspective, the explanatory or conversational context, or any such relativizing factor. Ellis endorses this fundamental distinction between essence and accident, adding that the most basic essential properties are "the causal powers of the most fundamental kinds of things, so that things of these same kinds, existing in any other world, would be disposed to behave in just the same ways" (2001, p. 8). He also thinks that essential properties are intrinsic properties, though he allows that not all intrinsic properties are essential, only those intrinsic properties that are had necessarily. Moreover, he understands "intrinsic" in a specific way: to be intrinsic, a property must be borne in such a way that it is causally independent of the bearer's history, location, surroundings, and so on. As Ellis (2001, p. 27) points out: "On this conception, properties are not in themselves intrinsic or extrinsic; they are had or possessed intrinsically or extrinsically."

The contrast between essential and accidental properties is supposed to apply in its purest form to fundamental particles such as electrons, which essentially possess all their intrinsic dispositional properties or causal powers (charge, mass, spin, and perhaps others). As for other properties, such as an electron's position, velocity, or excitation level within a particular atom, these are paradigmatically accidental properties, which are merely contingent, can be lost or gained without loss of identity, are not shared by all electrons, and are not characteristic of the natural kind or substance universal *electron*.[9] However, as Ellis recognizes, not all the entities and properties investigated by science fall cleanly on one side or the other of this divide, even if we restrict ourselves to basic physics. Consider two atoms of uranium, both of which have atomic number 92 (the same number of protons), but one of which has atomic weight 235 and the other atomic weight 238 (by virtue of having a different number of neutrons). Atomic weight would appear to be an intrinsic causal power of an individual atom of uranium. As Ellis (2001, p. 77) states about this case: "the intrinsic differences between them may make a very big difference in the way the two atoms are disposed to behave." However, having atomic weight 238 is not a property that characterizes all atoms that belong to the kind uranium, though it does characterize all atoms that belong to the kind uranium-238. Thus, a property such as atomic weight seems to have some of the hallmarks of an essential property, yet it also seems accidental in some respects. Ellis writes: "…the traditional distinction requires us to say that while the

[9] Concerning the connection between universals and natural kinds, Ellis (2001, p. 19) writes: "All universals are natural kinds, even property universals can be considered natural kinds, instances of which are tropes."

property of having atomic weight 238 is an essential property of an atom of ^{238}U, it is only an accidental property of an atom of uranium" (2001, p. 77). But he demurs from this move, which would contextualize the essence-accident distinction. Instead, Ellis introduces a third category of property, *incidental*, to cover cases such as atomic weight. He defines this third category as follows. If a property Q is not essential to a natural kind K, but is essential to a natural species of K, then any member of K that has Q has it incidentally, and is therefore a member of a natural species of K which has Q essentially (2001, p. 78).

I will argue that the introduction of the category of incidental properties leaves essentialists with a problem concerning essentialism about kind membership. If we ask whether incidental properties are had *necessarily* by their bearers and whether their bearers belong *necessarily* to the corresponding natural kinds, essentialists are faced with a dilemma. If they answer in the affirmative, asserting that atomic weight is a necessary property of a particular atom and that an individual uranium atom necessarily belongs to the isotope to which it belongs, then a uranium atom could not change its atomic weight (say by losing one or more neutrons) without losing its identity. But a change in atomic weight cannot generally lead to an atom becoming a *different uranium atom*, according to essentialist principles, since atomic weight is not essential to its membership in the kind *uranium*, and a change in this property cannot lead to a change in its kind membership. They might say that it is the same atom qua *uranium* atom, but a different atom qua *uranium-238* atom. But then there would be no absolute fact of the matter as to whether it is the same individual atom; it would depend on the kind we are interested in: *uranium* or *uranium-238*. On the other hand, if essentialists answer in the negative, denying that atomic weight is a necessary property of an atom and that an individual atom belongs necessarily to its isotope, then this would sever the connection between necessity and intrinsic causal powers. For it would imply that the fundamental causal powers and intrinsic dispositions of some entities in physics are not had necessarily. This negates one of the basic planks of the essentialist position, which equates intrinsic causal powers with essential properties.

Ellis might modify his position by saying that essential properties are those that are essential at *some* level of specificity, whereas accidental ones are those that are not essential at any level. But this does not provide a way out of the dilemma. This would mean that the essential properties include the strict essential ones and the incidental ones. But the same question arises as to the necessity of essential properties in this new sense. All essential properties are supposed to be necessary to their bearers, but it appears that their bearers can lose some of them without loss of identity. In the uranium case, a change in atomic weight (but not atomic number) would lead to an atom being the same atom of uranium, but a different atom of uranium-238. Alternatively, Ellis could say that essential properties are those that are essential at every level and accidental properties are essential at some or no level, but this would again sever the link between essential properties and intrinsic causal powers. It would render only some intrinsic causal properties essential, rather than all of them, as Ellis requires.

Faced with this problem, essentialists might say that natural kinds are maximally specific: there is no kind *chlorine*, just the kind *chlorine-37*. But this would also go against much of the intuitive appeal of the essentialist position, according to which the natural kinds are such things as *chlorine*, *gold*, *lead*, and so on. Moreover, in the particular case of atomic isotopes, one may need to be more specific still. Consider a level that is yet more specific than that of the isotope, namely that of the nuclear isomer, a metastable state of an atom caused by the excitation of a proton or neutron in its nucleus so that it requires a change in spin before it can release its extra energy. The element tantalum (atomic number

73) has two naturally occurring isotopes: ^{180}Ta and ^{181}Ta. Moreover, the first isotope has two stable isomers, the base state ^{180}Ta and the isomeric state ^{180m}Ta (which unlike most nuclear isomers is relatively stable with a half-life of at least 10^{15} years). When it relaxes to its base state, the isomer releases energetic photons in the X-ray range of wavelengths. This isomer of tantalum-180 has different intrinsic causal powers than the isomer with a lower energy excitation level. According to scientific essentialism, it therefore has a different set of essential properties at this level. Relative to the isomer level of specificity, energy excitation level is an essential property, though it is only incidental relative to the level of isotope, just as atomic weight is essential at the isotope level but incidental at the level of the atom. Finally, atomic number is essential at all three levels of description. In the case of many properties, there is no unequivocal answer to the question of whether a property is essential or not; it depends on the level of description.

Before concluding that the introduction of incidental properties constitutes a real problem for the essentialist, it may be worth considering another way of accomodating the fact that some intrinsic causal powers are not possessed necessarily by their bearers (since they can lose and acquire them).[10] To restore the connection between essential natures and intrinsic causal powers, one might dispense with incidental properties entirely and propose instead that when such causal powers are lost or acquired the bearer ceases to exist. For example, every time an atom undergoes an alteration in its atomic weight, that atom would cease to exist and a new atom would come into existence in its place. On this view, atomic weight would be an essential property (rather than an incidental property), one which cannot be altered without altering the entity in question. There are a number of problems with this view. One is that it goes against standard scientific descriptions of the process of radioactive decay and similar natural processes in which entities undergo changes in their intrinsic causal powers. Another problem with it is that, if it is applied to the case of isomers, mentioned above, it would entail that an atom could repeatedly be destroyed and created simply by becoming excited and then relaxing to its base state. Thirdly, essences and natural kinds would be maximally specific, as stated earlier, and would not include, for example, *uranium* and *tantalum* but *uranium-238* and *tantalum-180-isomeric-state*. Given these difficulties, it is understandable that Ellis introduces the third category of incidental properties, but I have argued that that move is problematic for other reasons.

In arguing that the introduction of the category of incidental properties poses a dilemma for essentialists, I have focused on claims about the essence of a particular entity that belongs to some natural kind, i.e. essentialism about kind membership (EM). By contrast, EK, which states that a kind has a set of essential properties necessarily, possessing them in every possible world in which that kind is instantiated, does not seem to be prone to this dilemma. However, it is open to the objection that with the addition of the category of incidental properties, the properties associated with a natural kind are no longer essential or non-essential simpliciter. Rather, the essentialness of a property to a natural kind must be relativized to a level of description. Essentialists maintain that the kind *uranium* is characterized by the essential property of having atomic number 92, while the more specific kind *uranium-238* is characterized by the essential properties of having atomic number 92 *and* having atomic weight 238. Though having atomic weight 238 is essential to the more specific kind, it is not essential to the more general kind (and it is not accidental either, but incidental). That is why we can no longer speak of properties being essential full stop, but must contextualize our talk of essences to a certain level of specificity.

[10] I owe this reply to an anonymous referee for this journal.

5 Hierarchy

Ellis' ontological scheme consists of three broad categories of universals: substances, properties, and processes, each of which contains a number of species, which are further divided into subspecies, until one reaches the most basic level of infimic species universals, which cannot be further subdivided. We have already encountered some of the rungs within the hierarchy in the category of substance, where the infimic species are kinds of fundamental particles such as electrons, protons, and so on. Similarly, in the category of property, the infimic species are universals such as the property of having negative electric charge of 1.6×10^{-19} C. In the category of process, the infimic species are such things as specific kinds of chemical reactions. Ellis (2001, p. 20) endorses what he calls the *hierarchy requirement* for all such universals: "the memberships of two distinct natural kinds cannot overlap, so that each includes some, but not all, of the other, unless there is some broader genus that includes both kinds as species." He explicitly rejects a more stringent hierarchy requirement endorsed by some other essentialists and natural kind theorists, which prohibits overlapping between two kinds unless one is wholly contained within the other. Instead, he states explicitly that two natural kinds may partially overlap provided they are species of the same common genus. So for example, among the kinds of chemical compound are *cupric compounds* and *sulfates*, which overlap one another, *copper sulphate* being a kind of compound in their area of overlap. Clearly, neither are all cupric compounds sulfates, nor are all sulfates cupric compounds. But presumably they are both species of the same common genus, namely *chemical compounds*. Such overlapping (or crosscutting) would be ruled out by the stricter hierarchy requirement, but is explicitly allowed by Ellis (2001, p. 56n.2). Hence, it is just as well that Ellis does not endorse strict hierarchy, since that would entail that some perfectly good categories in the basic sciences would have to be denied essences and would have to be considered non-natural kinds.[11]

As compared with the strict hierarchy requirement that Ellis explicitly rejects, Ellis' hierarchy requirement is weak. The weak hierarchy requirement would appear to be trivially satisfied within each ontological category by virtue of the fact that there is an overarching genus corresponding to each of the three broadest ontological categories: substance, property, and process.[12] Within each of these categories, universals can freely crosscut one another, since they all belong to the most general genus. This requirement only rules out crosscutting among universals in different ontological categories (e.g. substance and process); but allowing such crosscutting would presumably be committing a category mistake.[13]

Consider two atoms, one of chlorine-37 and another of argon-37. According to essentialism about kind membership, each of these atoms belongs necessarily to the kinds to which it belongs, and it would belong to those kinds in every possible world in which it exists. In fact, each of these atoms belongs to at least two kinds: the first atom belongs to the kind *chlorine atom* as well as to the kind that includes all atoms with atomic weight 37; the second atom belongs to the kind *argon atom* and to the kind that includes all atoms

[11] For a critique of the strict hierarchy thesis as applied to science, see Khalidi (1998).

[12] At least this is suggested by Ellis when he says that universals range "from the most general category-wide universals (which the members of any given category of things must all instantiate)…" (2001, p. 19).

[13] In Khalidi (1998), I have argued that it is just as well that natural kind theorists not embrace the stricter hierarchy requirement, since there are plenty of natural kinds that crosscut one another. But I will argue here that Ellis' endorsement of a weaker hierarchy requirement also poses problems for his essentialist view.

with atomic weight 37.[14] Atoms with the same atomic weight are called "isobars" by nuclear physicists, and the two categories *atomic element* and *atomic isobar* are overlapping categories neither of which is wholly contained within the other. Now imagine that the first atom loses one neutron. It continues to belong to the kind chlorine since it retains its atomic number (which is equal to the number of protons), but it ceases to belong to the kind with atomic weight 37. As in the previous section, we are confronted with two different answers as to whether it is still the same atom. Insofar as it still belongs to the kind *chlorine atom*, it is the same, but insofar as it belongs to the kind with atomic weight 37, it is not.

This problem is similar to the one encountered in the previous section, the main difference being that the kinds to which these individual atoms belong are not nested within one another, but crosscut one another. Ellis might rule out atomic weight as a genuine essential property of atoms, but it is not clear on what grounds he can do so. By his own lights, atomic weight is an intrinsic and fundamental dispositional property of an individual atom. Alternatively, he might opt for the strong hierarchy requirement rather than the weak one, but then a whole host of scientific properties would be ruled out as being non-natural (e.g. *atomic weight*), since they crosscut other categories within the same broad category. If Ellis admits such kinds into his ontology, then he subverts the link between natural kinds and causal powers; but if he banishes them, then he dismisses a range of perfectly good scientific categories with an act of philosophical legislation.

6 Essences and the Special Sciences

Ellis thinks that the doctrine of scientific essentialism applies mainly to basic physics and chemistry, although he allows that there are essences in some branches of the life sciences, particularly microbiology. This means that the vast majority of scientific theorizing is concerned with properties that do not have essences and with kinds that are not natural. It might be expected that the sciences that study the basic structure of matter and its properties would have a different ontological status from those sciences that deal with matter and energy at a higher level of organization and description. But it is one thing to claim that physics and chemistry describe the ultimate building blocks of the universe at the most fundamental level, and another to hold further that their kinds are natural while other scientific kinds are not. This section will examine the rationale for restricting essences to the non-special sciences. In the course of this examination, it will emerge that EK is a trivial thesis that can be made to apply not only to special-science kinds but also to artificial kinds, non-scientific kinds, and non-kinds. In addition, I will argue that although EM fails for many special-science kinds, it also fails for some of the most fundamental kinds of the basic sciences.

What grounds might there be for holding that physics and chemistry deal with essences while the other sciences do not? There would seem to be two main considerations. One consideration for denying that kinds in the special sciences are natural kinds with essences has to do with the specific nature of some of these kinds. For example, Ellis claims that biological kinds like species are historical in nature and have vague boundaries. The fact that species are historically or relationally delimited rules out the possibility that they have an essence associated with them, according to some essentialists. For others, the fact that

[14] The atom of chlorine-37 has 17 protons and 20 neutrons in its nucleus, while the atom of argon-37 has 18 protons and 19 neutrons in its nucleus.

species have vague boundaries is more damaging, given that there are intermediate forms that we are hard pressed to classify in one species or another. While this is not the place to enter into a detailed consideration of species essentialism, it is worth noting here that considerations sometimes advanced to show that species do not have essences are not deemed decisive by some philosophers, both essentialists and anti-essentialists. In this vein, Elliot Sober has countered some of the arguments purporting to show that species do not have essences. More recently, essentialist philosophers of biology such as Paul Griffiths, Joseph LaPorte, and Samir Okasha have defended the view that biological species have historical or relational essences.[15] Thus, some of the general reasons adduced for denying that species have essences are not decisive in this regard.

Another reason for maintaining that physics and chemistry deal with essences and natural kinds while the other sciences do not is that the former are concerned with material constitution whereas the latter focus on relational properties, causal roles, or functions. Sciences like geology, neurobiology, meteorology, fluid mechanics, parasitology, and others may be thought to be more concerned with extrinsic rather than intrinsic properties. Whether or not all kinds in the special sciences are extrinsic or relational, it appears as though there is a preponderance of relational kinds the special sciences. However, even if we grant this claim, why is it important? Presumably, because if we are interested not in the way in which kinds are materially manifested but in the causal roles of those kinds, then it does not seem possible to take an essentialist attitude towards them. Essences are thought to involve material constitutions rather than relational properties, or causal powers rather than causal roles. Notice, however, that if we are concerned with EK (the thesis that all members of kind *K* necessarily possess one or a set of properties if they are to belong to *K*), then there is nothing to rule out relational kinds from being associated with a set of essential properties. Consider the geological kind *glacier*. A glacier is a long-lasting river of ice that is formed on land and moves in response to gravity. The properties characterizing glaciers are at least partly relational. Nevertheless, these properties can be said to be necessarily associated with glaciers, and glaciers might be thought to possess such properties in every world in which glaciers exist. There seems to be no obstacle to saying that the kind *glacier* is necessarily the kind that it is, and that all glaciers necessarily possess the same set of properties in every possible world in which they exist.[16] If we accept the intuitions that scientific essentialists rely on when it comes to kinds such as *electron*, I would argue that the intuitions about kinds such as *glacier* are no worse off.

Generally speaking, relational kinds are not excluded from having essences, appearances to the contrary notwithstanding. Why might it appear as though relational kinds and properties cannot have essences? Though the reasoning for this claim is not always made explicit, it might proceed as follows. Essentialism about kind *K* states that all members of *K* necessarily possess one or a set of properties. If one of these properties is relational, then

[15] For these positions, see Sober (1980), Griffiths (1999), LaPorte (2004), and Okasha (2002).

[16] For related reasons, some proponents of rigidity have abandoned the project of extending rigidity to general terms, since virtually any general term can be considered rigid. For example, Soames (2000, pp. 250–251) writes: "Nor will it do to say that a predicate is rigid iff there is a unique property which it stands for that determines its extension at each possible world." He notes that this is not only true for natural kind predicates like *cow* and *animal*, since "the same could be said for any predicate: for any predicate F, and any world w, the extension of F with respect to w is the set of things that have, in w, property expressed by *being an F*. But there is no point in defining a notion of rigidity for predicates according to which all predicates turn out, trivially, to be rigid." Similar points have been made by Schwartz (1980) and Donnellan (1983). Cook (1980) defends rigidity about natural kind terms, but he does so on the grounds that natural kinds satisfy EM rather than EK.

it must involve the existence of some other entity. Thus, if there is some possible world in which that other entity or kind of entity does not exist, the relation would not be satisfied in that world. Consequently, members of *K* could not possess that property in every possible world, and there would be no essential property associated with *K*. However, the natural reply to this line of argument is that in those possible worlds in which the relevant relation is not satisfied, the kind would simply not be instantiated. In other words, there seems to be no way to disqualify a relational property from serving as the essential property of a kind, so long as it is understood that the kind is instantiated only in those worlds in which the relevant relation is satisfied. For example, one could consistently say that *sisterhood* is the property of being a female sibling in every possible world, and that every sister in every possible world has the property of being a female sibling in that world. In a world of only children, the kind *sister* would not be instantiated. Thus, there appears to be no prima facie obstacle to the existence of kinds with relational essences.

At this point, scientific essentialists may admit that relational properties can also be said to have essences and may conclude that relational kinds in the special sciences should not be deemed outside the scope of essentialism. In fact, the criticism I have lodged against scientific essentialism might be turned into a friendly amendment to the effect that the scope of the essentialist doctrine should be widened to embrace the special sciences. But I will now argue that there is little cause for essentialists to rejoice in this conclusion, because it can be used to show that virtually any kind or property no matter how artificial or arbitrary can conform to EK. Consider the category of *objects whose mass exceeds 64 kilograms*. This category would not normally be considered a kind, since the objects that belong to it have too little in common and the sole property that unites them does not figure in any interesting generalizations or explanations. Still, the category can be said to have an essence on the grounds that in any possible world, the category of *objects whose mass exceeds 64 kilograms* would be the very same category (even though the specific objects that fall under that category would change, as is the case with some of the kinds discussed earlier). What this shows is that the requirement that essences pertain essentially to the kinds with which they are associated can be satisfied not only by relational kinds in the special sciences, but even by highly artificial categories that would not normally be considered kinds at all. Thus, the fact that the kinds of the basic sciences satisfy EK is not something that distinguishes them from other kinds and even from non-kinds. Essentialism about kinds turns out to be a trivial thesis that is satisfied by virtually any category, whether natural or not, scientific or not.[17]

One response to the argument for the trivialization of kind essences might be to fall back on essentialism about kind membership (EM). Scientific essentialists may say that EM cannot be trivialized in the way that EK can be. That is because some properties and kinds hold of a certain individual in every possible world in which that individual exists, whereas others do not. Moreover, it might be thought that many of the kinds in the basic sciences are such that EM holds of them, whereas the kinds of the special sciences are such that their members do not belong to them essentially. In particular, it seems as though relational kinds cannot be made to comply with EM.[18] For example, in another possible world, a particular glacier might not have been a glacier but a flowing river (say, in a

[17] The argument in this paragraph draws on the debate concerning the rigidity of natural kind terms mentioned in the previous footnote, but that debate pertains to the semantics of kind terms rather than the metaphysics of kinds.

[18] The fact that a wedge can be driven between EK and EM when it comes to biological species has been explicitly noted by LaPorte (2004) and Okasha (2002).

counterfactual situation in which temperatures on earth were considerably warmer). Hence, it is not the case that some particular glacier, say the Athabasca Glacier, would be a glacier in every possible world in which it exists. This result may appear to vindicate essentialism, for although EK has turned out to be a trivial thesis, which applies to scientific kinds just as much as it does to artificial kinds and non-kinds, EM may be said not to be similarly satisfiable; indeed, it is not even satisfied by the relational kinds of the special sciences. But the problem with considering this a vindication of scientific essentialism is that EM has minimal relevance for science and it fails for some of the most fundamental kinds in the basic sciences.

Ellis (2001, p. 2) writes: "… it is impossible—metaphysically impossible—for a proton or any other fundamental particle to have a causal role different from the one it actually has." But despite the fact that it is phrased here in the singular, this claim appears to concern EK rather than EM. EM, the claim that a particular object or entity is necessarily a member of kind *K*, would not appear to have as much relevance for scientific theorizing, since it concerns individual members of scientific kinds rather than the kinds themselves. Indeed, the corresponding claim about kind membership when it comes to electrons, namely that it is impossible for some specific electron not to be an electron and that it would be an electron in every possible world in which it exists, is incoherent in light of modern physics. According to the indistinguishability principle, electrons and other fundamental particles cannot be tagged or labeled, so it literally makes no sense to make a claim about the essence of some specific electron or to speculate about what kind that very electron would belong to in another possible world. Since EM cannot be said to hold for the most fundamental entities in basic science, one cannot discriminate between the basic and special sciences on the grounds that EM fails for the latter. Hence, scientific essentialism cannot be vindicated by adverting to EM rather than EK.

Scientific essentialists like Ellis restrict essentialism to the basic, or non-special, sciences. When it comes to EK, I have argued that they do not have sufficient grounds for doing so. Moreover, the discussion has shown that EK is not an interesting thesis that picks out a privileged set of natural kinds, but rather a trivial thesis that applies to artificial kinds, non-scientific kinds, and even to non-kinds. As for EM, there does seem to be some reason for denying that it obtains for the special sciences, but essentialism about individual kind membership has less relevance to science than EK themselves, and it is inapplicable to some of the most fundamental scientific kinds of all.

7 Conclusion

In this paper, I have tried to argue that scientific essentialism is neither tenable nor is it a viable metaphysical basis for science. In Sect. 2, I argued that scientific essentialists are unable to justify the claim that their metaphysical necessities are genuinely different from semantic necessities. Then, in Sect. 3, I showed that these alleged metaphysical necessities cannot really be said to be *absolute* necessities, as scientific essentialists insist. In Sect. 4, I claimed that Ellis' threefold system, which divides properties into essences, accidents, and incidents, would force essentialists to concede that the essentialness of properties is a contextual matter and cannot be determined absolutely. After that, in Sect. 5, I argued that if Ellis admits certain scientific kinds into his ontology, then he subverts the link between essences and causal powers; but if he banishes them, then he dismisses a range of perfectly good scientific categories as being non-essential without good grounds. Finally, in Sect. 6, I argued that EK can be extended to the special sciences, but that it turns out to be a trivial thesis. As for essentialism about kind membership, though it may be ruled out for the relational kinds of the special sciences, it is also inapplicable to some of the most fundamental kinds in the basic sciences. I conclude that some of the main tenets of scientific essentialism have either not been adequately supported or are at variance with aspects of scientific practice.

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