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Natural Properties and Atomicity in Modal Realism

Abstract: The paper pinpoints certain unrecognized difficulties that surface for recombination and duplication in modal realism when we ask whether the following inter-world fixity claims hold true: 1) A property is perfectly natural in a world iff it is perfectly natural in every world where it is instantiated; 2) Something is mereologically atomic in a world iff all of its duplicates in every world are atomic. In connection to 1), the hypothesis of idlers prompts four variants of Lewis's doctrine of perfectly natural properties, all deemed unsatisfactory for the purposes of duplication and recombination. By means of 2), instead, we show that the principle of recombination does not countenance the atomicity or non-atomicity of duplicates; but it should, because it is genuinely possible that: a) something, which is atomic, is non-atomic; and b) something, which is non-atomic, is atomic. In discussing 1) and 2), the paper substantiates a tension in Lewis's metaphysics between modal intuitions and the reliance on the natural sciences.

Keywords: David Lewis, natural properties, modal realism, modal plenitude, principle of recombination, duplication

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Introduction

Lewis's modal realism crucially rests on the principle of recombination. This principle – to a first approximation – asserts that for any things there is a world containing any number of duplicates of each of those things, size and shape permitting. Duplication, in turn, is a relation among individuals: an individual *a* counts as a duplicate of another individual *b* if and only if *a* and *b* share all of their perfectly natural properties. Perfectly natural properties, also labeled as *fundamental* by Lewis (e.g. Lewis 1994, 474), are expected to be discovered by

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the natural sciences. The principle of recombination has been scrutinized from different angles in recent years. In this paper, we pinpoint and discuss certain unrecognized difficulties concerning duplication and its role in the principle. These difficulties surface when we ask whether Lewisian metaphysics is committed to the two following inter-world fixity claims, both of which involve perfectly natural properties (this is explicit in 1), while 2) involves them through the relation of duplication):

- 1) A property is perfectly natural in a world if and only if it is perfectly natural in every world where it is instantiated.
- 2) Something is mereologically atomic in a world if and only if all of its duplicates in every world are atomic.

It is notoriously controversial how naturalness should be understood within the framework of Lewisian metaphysics and the difficulties we pinpoint in this paper stem from this debate. Some important tensions within the Lewisian understanding of perfectly natural properties are already illustrated in his posthumous *Ramseyan Humility* (2009). Here Lewis discusses some (chiefly epistemological) problems posed by *aliens* (“those fundamental properties, if any, that are instantiated within unactualized possible worlds but not within the actual world,” p. 205) and *idlers* (“those fundamental properties, if any, that are instantiated within the actual world, but play no active role in the workings of nature,” p. 205). Some difficulties posed by alien properties have already been discussed by Lewis himself (1986a) and by Divers and Melia (2002): plenitude requires enlarging the base of recombination in an adequate way in order to also accommodate aliens, but the notion of adequacy at stake risks being modal as well. In addition, we wish to point out that the hypothesis of alien perfectly natural properties renders recombination methodologically heterogeneous since non-alien perfectly natural properties turn out to be discovered by the natural sciences, while alien perfectly natural properties are arrived at through sheer modal intuition. None of these difficulties, however, dig into the concepts of duplication and perfectly natural properties. Our paper aims to do exactly this, by analyzing fixity claims 1) and 2).

In particular, in connection to 1), we argue that the hypothesis of idlers prompts alternative variants of Lewis’s doctrine of perfectly natural properties. Three of these variants agree that the naturalness of perfectly natural properties depends on their having a nomic role. Yet, they disagree on whether this nomic role must be played in every world, or in at least one world, or in a particular world. Thus, they also disagree on the contribution that the natural sciences or sheer modal intuitions can offer in identifying perfectly natural properties. We argue that each of these three variants is problematic, and this leads to consider a more radical alternative, suggested by certain remarks in Lewis (2009, 204–5).

According to this alternative, perfect naturalness is a primitive feature of properties, independent of their role in relevant facts of resemblance and causality. According to such a reading, duplication is a straightforward affair, but perfect naturalness becomes a matter of stipulation. We are thus left with the unanalyzed metaphysical primitive of perfect naturalness, and this raises epistemological worries that run counter to pre-theoretical expectations about perfectly natural properties.

Claim 2) concerns another aspect of the doctrine of perfectly natural properties, namely the identification of their bearers. According to Lewis's doctrine of Humean supervenience, perfectly natural properties are instantiated only by points or point-sized entities (Lewis 1986b, x). If the kind of simplicity exhibited by points or point-sized entities is mereological atomicity, then only mereological atoms can instantiate perfectly natural properties. Yet, such an understanding of the relationship between perfectly natural properties and their bearers, cannot be extended to any possible world. Indeed, Humean supervenience was intended by Lewis to be a contingent doctrine primarily concerning our world (Lewis 1994, 474–5) and Lewis himself considers the remote hypothesis that there are no mereological atoms at all – the so-called gunk (cfr. Lewis 1991, 20–21). By contrast, it seems plausible to assume that the relation of duplication is independent of the atomicity or non-atomicity of the duplicates, because it is defined solely in terms of perfectly natural properties. When an atomic bearer of perfectly natural properties is recombined vicariously through its duplicates, modal plenitude requires that the atomic bearer have both atomic and non-atomic duplicates. But, because duplication is independent of the mereological level of duplicates, it cannot warrant that both atomic and non-atomic duplicates of an individual exist.

We proceed as follows. In the next section, we recapitulate the role of modal plenitude in modal realism and focus on a specific formulation of it. In the following section, we analyze fixity claim 1) and discuss it with respect to the specific cases of aliens and idlers. Next over, we review fixity claim 2) and point out its unwanted consequences for the principle of plenitude. Finally, in the last section, we conclude by articulating the contrast between modal intuitions and the reliance on the natural sciences in Lewis's metaphysics.

Plenitude and recombination

Plenitude is a desirable feature for any theory of possibility. When it comes to theories of possible worlds, plenitude obtains if and only if, for any way a world might be, there is a world that is that way. As Lewis himself recognizes,

however, this is a contentless recipe for a full-fledged modal realist rendition of plenitude as it boils down to the claim that “every world is identical to some world” (Lewis 1986a, 86). To deliver a contentful rendition of plenitude Lewis resorts to the so-called principle of recombination. This principle aims to spell out a metaphysical intuition – independent of available empirical evidence – according to which “anything can coexist with anything else [...] Likewise, anything can fail to coexist with anything else.” (Lewis 1986a, 88) In this section, we provide a formulation of the principle of recombination, arrived at by recounting some chief and well-known problems with Lewis’s formulation of the principle. By doing so, we also bring to light the heterogeneity between the metaphysical intuitions guiding recombination, on one hand, and the appeal to natural properties in developing such intuitions, on the other, given that the identification of those properties is deferred to the natural sciences by Lewis himself. The heterogeneity provides a context to address the problems with the principle of recombination discussed in the next two sections.

The first problem we aim to recount regards the interplay between the principle of recombination and Lewis’s take on the identity of individuals across worlds. The most straightforward formulation of the principle of recombination states that for any selection of entities, there is a world containing exactly them. This formulation, however, cannot be taken at face value within Lewisian modal realism. In fact, worlds are isolated and no individual is part of more than one world. That is, for Lewis, a world does not overlap with any other world and is closed under spatio-temporal distance (or any other natural relation sufficiently analogous to it; cfr. Lewis 1986a, 75).¹ To deal with isolation, Lewis introduces counterparthood, as a relation of similarity between entities inhabiting different worlds. Counterparthood, however, is not specific enough to express the principle of recombination because there are counterpart relations that privilege extrinsic properties. In these cases, counterpart relations hold on the basis of properties that involve not only their bearer but also its surroundings. For instance, consider the counterparts of the White House that are determined based on the fact that the building sits on the territory of the United States of America. If these counterparts were defining combinatorial possibilities for the White House, then it would be impossible to separate the White House from the United States territory.

To serve the purposes of recombination and attain plenitude Lewis introduces duplication, a relation of similarity among individuals that is expected to be

¹ The impossibility of spatiotemporally disconnected island universes can be seen as a problem with Lewis’s variety of modal realism, as remarked in McDaniel (2006), section VII. We shall leave this debate aside in this paper.

stricter than counterparthood, as well as fully determined and exempt from any kind of vagueness. While counterparthood involves properties of all sorts, for Lewis duplication should countenance only intrinsic properties. To this end, he first defines duplicates as those individuals that instantiate the exact same perfectly natural properties (cfr. Lewis 1986a, 62–63), where perfectly natural properties are the most basic kind of intrinsic properties. Secondly, he defines intrinsic properties as those that are shared by duplicates. Thus, duplication countenances only perfectly natural properties, which are a kind of intrinsic properties.

Duplication as intended by Lewis is cumbersome for a number of reasons, starting from the fact that the distinction between intrinsic and extrinsic properties is contentious and that Lewis himself offered different accounts during his lifetime (cfr. Lewis 1983b, 1986a, 2001 and Langton and Lewis 1998). For present purposes, it is specifically Lewis's theory of natural properties that raises concerns. This is not only because naturalness, as used by Lewis, is a slippery notion (cfr. Taylor 1993). More importantly, the epistemic foundations of the metaphysical intuitions about recombination, on one hand, and of the specific metaphysical theory, on the other, are heterogeneous. There are numerous passages where Lewis seems to claim that the identification of natural properties should be deferred to the natural sciences, and in particular to physics, as the following passage suggests: "physics discovers properties. And not just any properties – natural properties" (Lewis 1983a, 365). Thus, Lewis begins with metaphysical intuitions about recombination that are independent of empirical considerations; but, in the end, the intuitions are developed in terms of properties that are uncovered by the natural sciences, or physics alone. As suggested by Langton (1998) and by the subsequent debate on humility – including Lewis (2009) – the prospect that Lewis's views will converge into a cohesive package may remain undetermined and left to mere luck. The questions raised in the next two sections of this paper hinge specifically on the plausibility of assuming such convergence.

Moving on to a different set of considerations, let us assume for the sake of argument that an appropriate notion of duplication can be provided in Lewisian terms. Additional well-known difficulties concern a proper formulation of the principle of recombination. For instance, Nolan (1996) discusses whether it is possible to drop the proviso over the size and shape of the worlds obtained by recombination, which was initially required by Lewis (1986a, 89–90). We do not discuss the problem of the size and shape of the worlds in this paper. Later on, instead, we consider cases that are problematic for another reason – taken up by (Efird and Stoneham 2008) and (Darby and Watson 2010) among others – where an individual has more than one duplicate in the same world. Nothing dictates that there is only one duplicate for each entity that is recombined. When there is a different number of duplicates for one entity, we obtain different worlds,

corresponding to different ways in which the world could be. This element of complication has lead to a debate, which is still partially open, about the most proper formulation of the principle. An outcome of the debate is the following formulation of the principle of recombination, proposed by Darby and Watson (2010, 444):

(DW) For any sequence of individuals $x_1, x_2, x_3, \dots, x_m$ and any appropriate m -place spatio-temporal relation there exist numerically distinct individuals $y_1, y_2, y_3, \dots, y_m$ such that y_i duplicates x_i , and the y 's form a maximal spatiotemporally related mereological sum in that spatiotemporal relation.²

In this paper we assume (DW) as the target of our discussion of the principle of recombination. Before moving forward, it is important to point out two features of (DW), leaving aside other potentially contentious aspects discussed by Darby and Watson themselves (e.g. the requirement of appropriateness for spatio-temporal relations and the invoked notion of maximality). First, in the sequence of individuals $x_1, x_2, x_3, \dots, x_m$ we can find one and the same denizen several times. This guarantees that, for any individual, there are worlds including one duplicate of that individual, worlds including two duplicates of that individual, and so on. Second, it is noteworthy that the individuals to be recombined are not exclusively minimal parts or atoms or building blocks. Even the most macroscopic entity, such as a full world itself, is expected to appear one or several times in some sequence of individuals that is to be recombined.

Aliens, idlers, and duplication

In this section we discuss fixity claim 1) vis-à-vis a problematic kind of perfectly natural properties, namely the so-called idlers. Fixity claim 1) states that a property is perfectly natural in a world if and only if it is perfectly natural in every world where it is instantiated. Such a claim sits ill with the hypothesis of idlers. We begin, however, with the simpler and already partially studied case of aliens. This case serves to bring to surface the intricate interplay between modal intuitions and the reliance on the natural sciences. Indeed, since aliens cannot be discovered by the natural sciences, some stipulations driven by modal intuitions are required in order to supplement the notions of duplication and

² In this formulation of (DW), we made one small adjustment to the original formulation by Darby and Watson: we replaced the occurrences of 'objects' with occurrences of 'individuals.' The adjustment was made in keeping with Lewis's terminology.

recombination. Far less known, instead, are the issues raised by idlers. Idlers force us to choose one of four alternative notions of perfect naturalness. These alternatives cast severe doubts on the project of defining recombination in terms of duplication and natural properties.

Lewis himself recognizes that it is possible for some properties to be so far from those of a given world that they are alien to it. A property is alien to a world, if and only if: “(1) it is not instantiated by any inhabitant of that world, and (2) it is not analyzable as a conjunction of [...] natural properties all of which are instantiated by inhabitants of that world.” (1986a, 364) Alien individuals are those individuals that instantiate at least one alien property. It is at least plausible to hypothesize that, among the alien properties, some are alien perfectly natural properties. The latter hypothesis requires that some adjustments be made to the principle of recombination. If the input of recombination were the individuals inhabiting worlds that are not “especially rich” (Lewis 1986a, 92), from the point of view of the stock of perfectly natural properties, then plenitude would not follow. Therefore, the input of recombination should result from a selection of worlds that is broad enough for every perfectly natural property to be instantiated in at least one of these worlds.

Nonetheless, a complication arises. The specification of a selection of worlds that would secure plenitude with respect to the possibility of alien individuals turns out to be a tricky affair. As Divers and Melia (2002) argues, the requirement that should be imposed upon the recombining elements can only be formulated in a modal way. To some extent,³ this undermines the ambitions of Lewis’s modal realism to reduce modal talk and modal states of affairs to non-modal ones.

In addition to the irreducible modal character of the principle of recombination, it is important to point out that the hypothesis of alien perfectly natural properties renders recombination methodologically heterogeneous. From the point of view of Lewisian modal realism, it would be due to only sheer luck if we were to inhabit the world that is richest in its stock of perfectly natural properties. Prudence thus requires us to endorse a view according to which some perfectly natural properties cannot be discovered by the natural sciences. If we were to assume that the natural sciences could uncover all the perfectly natural properties of our world, therefore, the natural sciences could only partially uncover the relations of equivalence holding between the duplicates that form the basis of recombination. The remaining relations of equivalence are fixed, in a purely stipulative manner, by the modal intuition that suggests the existence of alien properties.

³ Cfr. Divers (2013) for a more thorough discussion of this point.

For instance, modal intuitions suggest that there are two worlds, that are different from the actual world, which share their domain of perfectly natural properties. Call these worlds, w_1 and w_2 . One of the perfectly natural properties instantiated in w_1 and w_2 is *Spin*, the perfectly natural property well-known in microphysics; moreover, some individuals in w_1 and w_2 instantiate *Psin* too, which is alien to our world. Now, take two particles, one in w_1 and one in w_2 , which match in Spin value and differ in Psin value. If the natural sciences in our world were the only guide to duplication, the two particles would be duplicates. But the modal intuitions that guide us in accepting this example as a genuine possibility suggest otherwise. The heterogeneity of duplication is a clear example of the tension between the naturalistic foundations of the doctrine of perfectly natural properties, on one hand, and the indispensability of brute modal intuitions to a satisfying analysis of modality, on the other.

The troubles with the principle of recombination that arise when we confront fixity claim 1) with the possibility of idlers are much more intricate. A property is an idler in a world if and only if in that world it does not play the role that the perfectly natural properties are expected to play, but it does play that role in some other worlds. As in the case of aliens, Lewis endorses the possibility of idlers by appealing to modal intuitions that are independent of – and eventually turn against – our best available empirical evidence. The theoretical implications of endorsing the hypothesis of idlers have been widely discussed in the context of so-called *humility*.⁴ Still waiting to be explored, instead, are the implications of the hypothesis for recombination, duplication, and naturalness. The admission of idlers introduces a potential variability for the domain of perfectly natural properties, which is additional and more subtle with respect to the variability determined by aliens. We propose to analyze such variability by means of three alternative conceptions of perfect naturalness. The hypothesis of idlers – we argue – requires us to decide if the perfect naturalness of a property depends on whether the property is idle at *some* world, at *all* worlds, or at a *specific* world. We argue that each of the three theoretical options leads to further problems. This ultimately leads us to entertain a fourth take on perfectly natural properties, according to which naturalness is a primitive feature of some properties.

In order to introduce the topic, we begin with some examples. Consider three worlds – w_1 , w_2 , and w_3 – and three particles, one for each of the worlds: p_1 , inhabiting w_1 ; p_2 , inhabiting w_2 ; and p_3 , inhabiting w_3 . Additionally, suppose that each particle instantiates the following three properties, with the exact

⁴ Cfr. Langton (1998), Lewis (2009), Leuenberger (2010), and Kelly (2013).

same value: *Spin*, *Charge*, and *Psin*. Let us further suppose that: none among *Spin*, *Charge*, and *Psin* is idle in w_1 ; *Spin* and *Charge* are not idle in w_2 , but *Psin* is idle in w_2 ; *Spin* is not idle in w_3 , but *Charge* and *Psin* are idle in w_3 . The question arises as to whether, for a modal realist, duplication holds between p_1 , p_2 , and p_3 , when considered pairwise.

According to the first proposal, that we label *Somewhere-naturalness*, a property is perfectly natural if and only if, at least at one world, it “plays an active role in the workings of nature” (Lewis 2009, 205), that is, it underlines the relevant facts of resemblance and causality (Lewis 1983a). If we endorse *Somewhere-naturalness*, then *Spin*, *Charge*, and *Psin* count as perfectly natural in w_1 , w_2 , and w_3 . More generally, *Somewhere-naturalness* guarantees the truth of fixity claim 1) because, given any property, either there is a world where the property at stake is non-idle (and, therefore, the property is perfectly natural), or there is no such world (and, therefore, the property is not perfectly natural); there is no way in which a property could be perfectly natural at one world and not perfectly natural at another world.

However, consider a fourth world – w_4 – inhabited by a particle p_4 , which non-idly instantiates *Spin* and *Charge* exactly like p_2 . *Psin* is instantiated by some particle and idle in w_4 , but it is not instantiated by p_4 . Now, according to *Somewhere-naturalness* p_2 and p_4 are not duplicates because they do not share all of their perfectly natural properties (they differ with respect to *Psin*). Such a result, however, is counterintuitive from the point of view of the natural sciences of w_2 and w_4 , since *Psin* does not play any role in the workings of these worlds. Even more relevantly, for the modal realist there are infinitely many worlds inhabited by particles that, like p_4 : non-idly instantiate *Spin* and *Charge*; do not instantiate *Psin*; and inhabit worlds where *Psin* is idle and instantiated. Once again, this example points to the tension between the naturalistic twist of the doctrine of natural properties and the need to account for our brute modal intuitions.

Somewhere-naturalness is restrictive in admitting relations of duplications: intuitively p_2 and p_4 should be duplicates, but they turn out not to be such. We can nonetheless envisage alternative understandings of perfect naturalness and, thus, duplication. According to the second position, that we label *Everywhere-naturalness*, a property is perfectly natural if and only if, at every world where it is instantiated, it plays an active role in the workings of nature. *Everywhere-naturalness*, however, fails to deliver a viable notion of duplication. Indeed, if we concede that any property could be instantiated and idle at some world, then no property at all turns out to be perfectly natural, and fixity claim 1) is trivially true. The claim that any individual is a duplicate of any other turns out to be equally trivial because it is true – in a vacuous way – that any two individuals

share all their perfectly natural properties. As a result, according to *Everywhere-naturalness* it would be strikingly arbitrary for the basis of recombination to include any choice of individuals whatsoever. Therefore, unless some principled way to restrict the brute modal intuition that any property can be instantiated and idle at some world is found – and we presently have nothing of the like to offer – *Everywhere-naturalness* cannot be endorsed by the modal realist.

The third and final option for understanding perfect naturalness that is worth considering is *Worldbound-naturalness*. According to this option, a property is perfectly natural relatively to a world, if and only if at that world the property is non-idle and instantiated. *Worldbound-naturalness* avoids the pitfalls of *Somewhere-naturalness*, because it makes p_2 and p_4 duplicates. Moreover, unlike *Everywhere-naturalness*, it can deliver a discriminating notion of duplication. Finally, with *Worldbound-naturalness* it is up to the natural sciences to discover the perfectly natural properties. However, *Worldbound-naturalness* leads to a systematic variability in the domain of perfectly natural properties and, thus, clashes with fixity claim 1). To warrant plenitude, then, *Worldbound-naturalness* requires that the basis of recombination be adequately large to include at least one instance for any property that is non-idle in the workings of at least one world. To fulfill this requirement, however, we must already know what is active in the workings of every world. Thus, in order to determine the basis of recombination we are expected to know in advance a substantive part of the results of the recombination. This seems to make the principle partially contentless, while the initial purpose of the principle was to generate an adequate and contentful analysis of our intuitions about combinatorial possibilities.⁵

The three options we have just discussed agree that the naturalness of perfectly natural properties depends in some way on their having a nomic role. The problems encountered by each of them suggest a fourth and more radical alternative, where the order of explanation between the nomic role and naturalness is inverted. It is not that perfectly natural properties are properties that play a role in natural laws; rather, laws (notoriously conceived by Lewis as regularities) inherit their status by involving perfectly natural properties. This idea is hinted at by Lewis in the following passage:

⁵ A reader may be tempted at this time to invoke yet another take on naturalness, where naturalness would be fixed only for a cluster of worlds (e.g. worlds sharing some fundamental natural laws). According to this take, a property is perfectly natural relatively to a *cluster of worlds* if and only if, at that cluster of worlds, the property is non-idle and instantiated. Alas, even this proposal falls victim of the problem just pointed out with respect to *Worldbound-naturalness*.

The properties that figure in the fundamental laws of nature are natural, but that is not because figuring in the laws makes them natural. Rather it is because regularities are fit to compete for the status of lawhood only when formulated in terms of perfectly natural properties. (Lewis 2009, 218, footnote 2)

This fourth perspective makes perfect naturalness a primitive feature of properties, independent of their role in relevant facts of resemblance and causality. The element of primitiveness is introduced specifically for the purpose of making duplication a straightforward affair, a result easily obtained by maintaining that perfectly natural properties cannot vary between worlds. This is a clear advantage over the three previous alternatives. On the other hand, perfectly natural properties become an unanalyzed metaphysical primitive; that is, it is a brute fact that some properties are perfectly natural. Given the foundational roles that perfectly natural properties play in modal realism, leaving their identification to a primitive and intuitive idea empties their explanatory power.

Atomic and non-atomic duplicates

In this section we discuss the problems raised about modal plenitude by fixity claim 2) – that is, the claim that something is mereologically atomic in a world if and only if all of its duplicates in every world are atomic. Our discussion in the previous section relied on the possibilities of aliens and idlers, which are already entertained in the relevant literature (including Lewis's works). In the case at stake in this section, by contrast, we need to show that some scenarios are genuinely possible before arguing that Lewis's take on duplication is unable to account for them and, thus, that modal realism fails to attain plenitude. In particular, we argue that plenitude fails because the principle of recombination does not countenance the atomicity or non-atomicity of duplicates; but it should, because the following two scenarios seem to be genuine possibilities: a) the possibility that something, which is atomic in our world, is non-atomic in another world; and b) the possibility that something, which is non-atomic in our world, is atomic in some other world. These are *kinds* of possibilities in the sense that the possibility that atomicity and non-atomicity vary should be conceded for several entities, so that for any of these entities we risk incurring a failure of plenitude.

First consider the kind of possibility a), where something atomic is instead non-atomic. According to the counterpart-theoretic understanding of *de re* possibilities associated with modal realism, the possibility that an entity *t* is atomic

requires the existence of at least one atomic *counterpart* of *t*, while the possibility that *t* has proper parts requires the existence of at least one non-atomic counterpart of *t*. The same individual is allowed to have more than one counterpart in one and the same world. Thus, nothing in the theory of counterparts forbids the existence of two counterparts of *t* in one world, one atomic and the other non-atomic.⁶

Is a) a genuine kind of possibility? Is it genuinely possible for something atomic to be non-atomic? Take an allegedly minimal, atomic part of our world: an electron. Many particles that in the past were regarded as atomic, later turned out to be mereologically complex. Some of them were so firmly thought to be devoid of proper parts that they deserved to be called “atoms”, and are still called such by physicists. So, could an electron have proper parts? The hypothetical argument for the essential atomicity of electrons may appear as (un)supported as past arguments for the atomicity of physical atoms have been. We are unable to provide an example of proof in metaphysics or science of the essential – and, as a consequence, necessary – atomicity of something. Still, from an epistemological point of view, the prospect of discovering that electrons have proper parts cannot be ruled out and it finds support in historically analogous precedents. The use of epistemological evidence in arguing about modality is notoriously controversial; yet, in every case at stake, it is not clear just what could prove that something we could discover epistemically is instead metaphysically impossible.

At this point, those willing to deny that a) is a genuine kind of possibility could appeal to so-called *mereological essentialism*, according to which all individuals have their parts essentially.⁷ A specific instance of this position would be that, if something has no parts in a given world (and in particular in ours), then it cannot have parts in any other world. Obviously, mereological essentialism should be adapted to Lewis’s modal realism, according to which worlds do not overlap and, as a result, the counterpart of *t* in a different world cannot share any part with *t* at all. Once adapted, mereological essentialism

⁶ The possibility that *t* is atomic would be already warranted by *t* itself, insofar as the counterpart relation is reflexive. But, the atomicity of *t* is compatible with many possible varieties of features in what surrounds *t*. Thus, plenitude requires several different worlds in which at least one counterpart of *t* is atomic.

⁷ The kind of *mereological essentialism* we have in mind was first elaborated by Roderick Chisholm and presented by him in several works, most notably Chisholm (1973) and Chisholm (1976), ch. 3.

would require only that parthood relations be preserved by counterpart relations. If t' is a counterpart of t , then, necessarily, for each and every proper part s of t , there is exactly one proper part s' of t' that is a counterpart of s (and t' has no other proper part that is not a counterpart of a proper part of t). If we assume mereological essentialism then, supposing that electrons are atomic in our world, the counterpart of an electron cannot be but atomic.

Mereological essentialism is a controversial position when it comes to time and change, since it would require that, when I lose one of my hairs, strictly speaking I become another person. It is not less controversial in the modal domain. Strictly speaking, the above counterpart-theoretic version of mereological essentialism leads to the conclusion that any counterpart of mine has exactly one hair for each hair of mine; as a consequence, not only could I not be bald, but I could not even have one more hair or one less hair than I already do. This seems like a bold way to take the modal facts wrong, and much more severe than the failure of plenitude concerning atomism that we are accrediting to modal realism. Conjoining modal realism with mereological essentialism leads to a much more extensive failure of plenitude.

The mereological essentialist could simply insist that the apparent failure of plenitude is a misleading appearance, since the modal facts *are* that I cannot be bald, and that I cannot have one hair less or one hair more than I already do. At any rate, such a radical form of modal fixity seems incoherent with the original motivations of mereological essentialism. The extension of mereological essentialism to the modal sphere, and in particular its integration with counterpart theory, generates an unstable theoretical compound, that is in tension with its own motivations. The endorsement of mereological essentialism was motivated by the need to preserve a strict sense of identity for which the principle of indiscernibility of identicals holds at full strength. The fact that, *prima facie*, I can change in time, and in particular I can lose parts (for example, a hair) shows that so-called inter-temporal identity does not obey the principle of indiscernibility of identicals and, as a consequence, should not be mistaken for strict identity, of which the principle of indiscernibility is a constitutive principle. Once counterpart theory and modal realism take the stage, strict identity is no longer a concern. Denying overlaps between worlds rules out strict identity between worlds. Adapting strict identity to counterparts, requiring the preservations of parthood relations, is not a way to preserve strict identity in its full strength: counterparts in different worlds are not identical in any case. In sum, mereological essentialism is not fit to be integrated with modal realism and counterpart theory and, as a result, it does not legitimate modal realism and counterpart theory to deny that it is genuinely possible that something atomic is instead non-atomic.

The situation changes, in part, when we consider the other kind of possibility – b) – that is the possibility that something that has proper parts is instead atomic. The counterpart-theoretic analysis of this kind of possibility, for a non-atomic entity t , would require at least an atomic counterpart t' . In specific cases, there appears to be good reason for rejecting b) in virtue of some mereologically essential ties. Consider an entity a , such that some of its essential features are grounded in some of its functional parts. In this case, the hypothesis that the entity lacks functional parts could imply that it also lacks essential features. For example, a peppermill is expected to be of help in milling pepper, and it would not be of help if it were to lack a concave part where the pepper is inserted before being milled.

Any such example of mereologically essential ties is somewhat controversial, insofar as no uncontroversial method to identify essential features of entities is available and the doubt that the feature could be implemented in another way is difficult to repress. After all, why should pepper be inserted in a concave part? Could it not instead form a heap over a plane surface before being milled? However, these doubts about the specific examples are unable to outweigh the intuition that, in some cases, having certain parts – and, as a consequence, having parts in general, i.e. being non-atomic – is necessarily connected with some essential features.

The admission that some features of entities are grounded in some of their parts is not difficult to integrate with counterpart theory. In our example, nothing could count as a counterpart of a peppermill, if it were to lack a concave part. This implies that nothing can be a counterpart of a peppermill and be atomic at the same time.⁸ However, there is no good reason to extend this line of reasoning to everything, so that everything has an essential feature grounded in some of its parts. The decision about what to exclude from this line of reasoning depends strongly on the kind of essentialism adopted. Perhaps some things – such as mixed heaps of many different things, or gerrymandered mereological fusions of heterogeneous stuff – have simply no essential features at all. In

⁸ The possibility for a peppermill to be atomic would be easily regained by adopting the contextualized and relative kind of essentialism that is standardly associated with Lewis and counterpart theory: according to this kind of essentialism, anything can be the counterpart of anything, according to our interest and perspective. A sufficiently relaxed counterpart relation could release a table as a counterpart of the peppermill. The relation between counterpart theory and essentialism is characterized briefly in Lewis (1968), while that between modal realism and essentialism is discussed in Lewis (1986a, §4.5). However, this kind of contextualized essentialism is not really implied by modal realism and counterpart theory, thus we do not rely on it when arguing that it is genuinely possible for something actually non-atomic to instead be atomic.

absence of a generalized mereological essentialism (which, as we have seen above, is not fit to be integrated with counterpart theory and modal realism), there is nothing wrong in admitting that they could be atomic.

One more argument can be made in support of b), assuming a). If the kind of possibility a) is genuine, then it is genuinely possible – say – that an electron is not atomic. Thus, there are non-atomic counterparts of electrons. Let us focus on these counterparts of electrons. They are non-atomic by hypothesis. Could they be atomic instead? We cannot rely on the formal features of the counterpart relation to answer the question, since in general the counterpart relation is not symmetric (and thus, in some cases, t' is a counterpart of t , while t is not a counterpart of t'). But in the specific case under consideration, the burden of proof seems to be upon the denier: if it is genuinely possible for an atomic electron to be non-atomic, why should it be impossible for a non-atomic counterpart of an electron to be atomic?

We have shown that kinds a) and b) of possibility are plausible. The reasons are stronger and more general for a) than for b), but in both cases the burden of proof seems to be upon those who wish to deny that they are genuine possibilities. Therefore, the world could be such that what is atomic is instead non-atomic, or could be such that what is non-atomic is instead atomic. Obviously, it could also be such that what is atomic is still atomic (while other features of the world could vary), and such that what is non-atomic is still non-atomic (while other features of the world could vary). If plenitude holds for modal realism (and modal realism, as a result, takes the facts of modality right), there should be possible worlds that correspond to each of these possible ways in which the world could be.

Next, we prove that the principle of recombination does not warrant plenitude for the kinds of possibilities a) and b), beginning with the former. The principle of recombination is about duplicates. In order to count as a duplicate of an electron in our world, an individual in another given world must share with it all its perfectly natural properties, such as its spin and charge. This, however, does not guarantee that the duplicate of the electron is a minimal part of the given world. Why should the essential features of an electron – shared by all its duplicates – guarantee its atomicity at all worlds? Perhaps, there is a kind of nomological connection between the perfectly natural properties of electrons and their atomicity. But, Lewis's realm of possibilities extends beyond that which is nomologically possible. In this broader domain of possibilities, the sharing of charge and spin does not imply that the duplicate of the electron has no proper part, as electrons do in worlds like ours. For instance, while our world may be non-gunky, the duplicate may inhabit a gunky world, and the candidate to be the duplicate of the electron could be gunky itself. In a gunky state of

affairs, or in a completely gunky world, perfectly natural properties are not instantiated exclusively by atoms for the simple reason that there is no atom in such worlds.

The principle of recombination, being defined on perfectly natural properties, remains silent circa the homogeneity of atomicity across worlds. As a result, it does not warrant that there are enough worlds to represent all the ways in which the world might be with respect to a certain electron. The recombination delivers a world with one duplicate of the electron, another world with two duplicates of the electron, and so on. But it does not warrant that the electron has atomic, non-atomic, and gunky duplicates.

Let us focus on an atomic part a of a world, and on Darby and Watson's formulation of the principle of recombination – (DW) – provided in the first section

(DW) For any sequence of individuals $x_1, x_2, x_3, \dots, x_m$ and any appropriate m -place spatio-temporal relation there exist numerically distinct individuals $y_1, y_2, y_3, \dots, y_m$ such that y_i duplicates x_i , and the y 's form a maximal spatiotemporally related mereological sum in that spatiotemporal relation.

Sequences can include an electron multiple times. Thus, for any number n , we obtain a world where there are at least n duplicates of a . We are, however, unable to represent the genuine (kind of) possibility that in some worlds all the duplicates are atomic, in others no duplicate is atomic, and in still others some duplicates are atomic and some are non-atomic. This (kind of) possibility could be represented if the parts of a were duplicates of other entities (these other entities could be included, or not, in the sequence of individuals to be recombined). But the existence of these other inputs for the principle of recombination is not secured by the recombination of a itself or of the proper parts of a since, by hypothesis, a has no proper part.

As a result, given two ways in which the world might be, say, the way in which there are two a -like atomic entities and the way in which there are two a -like entities, one atomic and the other non-atomic (perhaps even gunky), the principle of recombination does not secure the existence of two worlds for these two ways in which the world might be. Therefore, the principle of recombination supported by modal realism fails to attain plenitude.

If we consider the type of possibility b), the failure of plenitude is a bit less straightforward. Take a physical atom, and call it "Atom." Atom could figure one or many times in the sequence of individuals to be recombined in (DW). Given a sequence, there would be a corresponding number of distinct duplicates of Atom in a certain world. Let us focus on the worlds with two duplicates of Atom. The principle of recombination is unable to warrant that, in general, we get a world where both duplicates of Atom are mereologically atomic, another where both

duplicates of Atom are mereologically non-atomic, and yet another where one duplicate of Atom is mereologically atomic while the other is mereologically non-atomic.

In attempt to accommodate possibilities of kind b), a modal realist could say that the parts of t could be included or not in the sequence of individuals to be recombined. When at least one part of t is included in the sequence, the principle of recombination generates a world where at least one duplicate of Atom has parts. By contrast, when no part of t is included, the principle of recombination cannot generate such a world. Nonetheless, this strategy does not lead to plenitude. Indeed, it fails to warrant that the duplicates of the parts of Atom are parts of the duplicates of t . In the absence of an explanation of the role of the parts of non-atomic entities in warranting their atomic and non-atomic duplicates, we can conclude that the principle of recombination, at least in its present form, also fails to secure plenitude for the kind of possibility b).

Conclusion

Fixity claims 1) and 2) bring to light a tension between sheer modal intuitions and the reliance on natural sciences in Lewis's metaphysics. When confronting 1), this tension leads to a dilemma: either the naturalness of properties rests on their nomic role or it is a primitive notion. If the former, then the natural sciences can guide us in uncovering perfectly natural properties; alas, the three alternative specifications of this approach are unsatisfactory because they make the domain of natural properties too variable among worlds (*Worldbound-Naturalness*), too inclusive (*Somewhere-Naturalness*), or empty (*Everywhere-Naturalness*). If the latter horn of the dilemma is chosen, then the primitive identification of natural properties is left to modal intuitions.

The analysis of 2) conveys the tension in a less direct, but no less important, fashion, moving it to an area that, properly speaking, is simply neglected by the principle of recombination. The principle, in fact, is blind to the mereological level of individuals, since duplicates are defined solely in terms of shared perfectly natural properties. On one hand, intuitions about plenitude lead us to deny 2), that is, to regard atomicity and non-atomicity as contingent features of individuals, which are subject to variation across worlds. On the other, it is tempting to defer to the natural sciences the question of whether our world is atomic and whether – provided that essentialism in general is regarded as an option – mereological essentialism holds. Therefore, atomicity and non-atomicity constitute another area where sheer modal intuitions and empirical evidence could clash.

Some of Lewis's works – in particular those that are not directly concerned with modal realism, such as Lewis (1983a) – defer to the natural sciences the identification of perfectly natural properties. But, the resulting image is not fit to serve the purposes of the notion of duplication and of the principle of recombination. In addition, it is unclear what alternate take on naturalness could replace the one embedded within Humean supervenience. The appeal to modal intuitions is subject to the usual objections according to which intuitions are subjective, incoherent, or ungrounded. Of course, one of Lewis's goals was to provide a philosophical analysis of modal intuitions (cfr. Divers 2013). This is precisely where the relevance of fixity claims 1) and 2) can be appreciated. Their scrutiny in this paper demonstrated that the project of analyzing our modal intuitions in terms of a principle of recombination fails because it cannot be paired with a suitable notion of duplication, for two reasons: first, because a viable notion of perfectly natural property is not available to serve the purposes of duplication; second, because duplication neglects the atomicity or non-atomicity of individuals.

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