Graph-Theoretic Models of Dispositional Structures

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The focus of this paper is the view about fundamental natural properties known as dispositional monism. This is a holistic view about nature, according to which all properties are essentially interrelated. The general question to be addressed concerns what kinds of features relational structures of properties should be thought to have. I use Alexander Bird's graph-theoretic framework for representing dispositional structures as a starting point, before arguing that it is inadequate in certain important respects. I then propose a more parsimonious graph-theoretic system which, among other things, overhauls Bird's distinction between stimulus and manifestation relations.

1. Introduction

In Alexander Bird's book *Nature's Metaphysics: Laws and Properties* (2007a) and his 2007b article, he offers a dispositional theory of properties (explained below) and provides a way of representing structures of dispositions using the resources of graph theory. These graphs may be regarded as representing what the world could be like in terms of the natural property structure that obtains. Not any graph whatsoever can successfully represent a possible property structure, however. At various points in his work, Bird suggests that four main constraints should be put into place, so that some of the important features of dispositionality are respected. After outlining Bird's account I will dispute the way Bird understands the nature of dispositional interaction, and this will lead me to reject one of his constraints and to propose a new graph-theoretic system. More precisely, I will begin by arguing, for both empirical and metaphysical reasons, that disposition manifestations are typically *mutual* manifestations of reciprocal dispositions working together. Thus, I support Martin (1993) and Heil's (2003) view of dispositional interaction. This leads me to the conclusion that the stimulus relations (discussed below) in Bird's property graphs should be eradicated, bringing the advantage of making the graph-theoretic framework more parsimonious. This modification then leads to two further ones: first, we should allow that some manifestation relationships may have more than three terms, and second, we should allow that some dispositions may manifest spontaneously, of their own accord. Not only are there empirical reasons for accepting these further modifications, they also serve to reconcile the mutual manifestation model with Bird's other graph-theoretic constraints. Thus, the mutual manifestation model proposed cannot simply be rejected by Bird and his followers on the basis that it unavoidably clashes with their other graph-theoretic commitments. Finally, I will discuss a feature of property structures not discussed by Bird, namely, that some elements in the structures will not be the manifestations of any others. Again, I suggest empirical reasons for thinking that this feature is not problematic.

2. Bird's Account

Bird's starting point is the view of natural properties known as *dispositional monism,* a view originally advocated by Shoemaker (1980) and currently held by Mumford (2004) and Bird himself, among others. The central claim of this view is that all natural properties (and relations) are nothing but dispositions for further manifestations. On this view, the nature of the property of being charged, for example, consists in an orientation to towards certain behavioural manifestations, such as acceleration, which may be manifested by a charged particle in an electro-static field.[1] Given that the nature of a disposition is *entirely* determined by the kind of manifestation(s) that it is a disposition for, the dispositional monists are, as Mumford highlights, left with a holistic view on which all properties 'form an interconnected web' (2004, 182). More specifically, on Bird's account, properties are connected by internal second-order 'manifestation relations' (2007b, 527). These relations are second-order in the sense that they hold between the properties *themselves*. (First-order relations, on the other hand, hold between the particulars things that bear such properties). To say these relations are internal is to say that they hold essentially, doing justice to the fact, indicated above, that the very identity of a disposition is determined by its directedness to a certain kind of manifestation. Of course, on the dispositional monist picture, these further manifestations will themselves be dispositional in nature, and so will essentially bear further second-order manifestation relations to further manifestation properties, and so on. On Bird's view, these manifestation relations are best understood as relations between properties construed as universals, but perhaps such relations could also be understood as holding between classes of property tropes. In any case, the key point for our purposes is that, on this view, manifestation relations constitute the nature of the fundamental properties of the natural world.

As indicated already, Bird goes on to offer a way of representing relational structures of properties. Following Dipert (1997), who holds that *particulars* are relational in nature, Bird appeals to the resources of graph theory (with some modifications). These graphs involve nodes (or 'vertices') which are connected via directed lines (or 'arcs'), with the nodes representing the properties, and the directed arcs representing the internal manifestation relations in which those properties stand. These relations have a direction because, generally, the relationship between a disposition and its manifestation property is asymmetric. For example, whilst acceleration is a manifestation of a particle's being charged, being charged is not the manifestation of acceleration. Bird also adds that the nature of a property is determined by the kind of stimulus which prompts the manifestations in question, and so he adds to his framework directed arcs corresponding to stimulus relations. To return to the charged particle case, we might say for example that the properties of the electro-static field are responsible for the stimulation of the charged particle's disposition to accelerate, a fact that must be reflected in our property graphs. Now, in Bird's graphs, arcs containing colored-in arrows correspond to manifestation relations and arcs containing clear arrows correspond to stimulus relations. Stimulus and manifestation relations which concern the same property (i.e. form a three-place stimulus-manifestation relationship) are represented by arcs which share the same line hatching. Figure 1 represents Bird's example of a six-node dispositional graph (2007b, 533, in Figure 10).

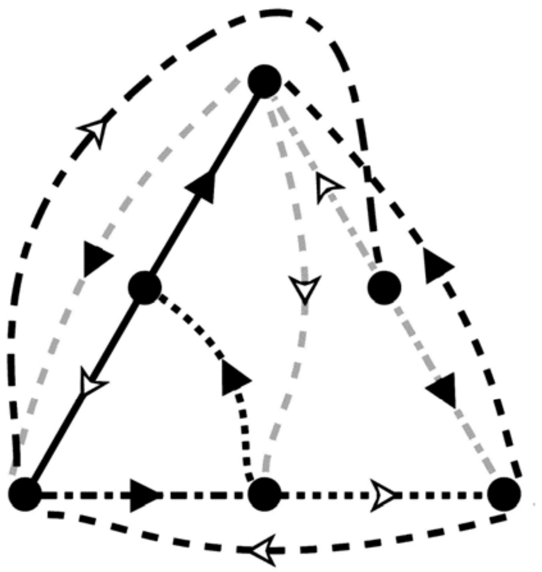

Figure 1 Bird's Six-node Graph (Reproduced Courtesy of Wiley-Blackwell).

As suggested earlier, such graphs may be understood as representing what a world may be like in terms of the property structure that obtains.[2] Not any graph whatsoever may represent a property structure that is genuinely possible, however. As Bird points out, an axiom of the graph-theoretic system must be that dispositional structures are asymmetric, which is to say, using graph-theoretic terminology, that property graphs must not be susceptible to any non-trivial automorphisms (2007b, 528). [3] Great importance is placed on this constraint, because with it in play a response becomes available to a regress objection that is often raised against dispositional monism.[4] Critics have worried that because, according to dispositional monism, the identity of each and every property is fixed by its relations to further properties, when we come to pinning down the identity of property, we either set off on an infinite regress of manifestation relations or come back around in a circle to the property in question (see Lowe 2006, 138 for example). As a result, the identity of a property can never be fixed. It seems this worry can be assuaged if all dispositional structures are asymmetric, however. As Bird points out, if this is the case then the identities of properties are '…fully determined by the asymmetric pattern of those structures' (2007b, 534). That is, if each property has unique relational features (in virtue of asymmetry), each property will be distinguishable from every other. Will it merely be a happy co-incidence if the property graph of our world is asymmetric in this way, or is it that such graphs are asymmetric necessarily? Although Bird does not appear to address this question, the answer seems to be that they are indeed asymmetric by necessity. Given that the nature of a disposition is exhausted by its manifestation (and stimulus) relations, there can be no question of a graph representing two distinct properties which share all the same relational features. In other words, the principle of the identity of indiscernibles seems to be true on the dispositional monist picture, at least in the case of properties. This is because if 'two' properties did bear the same relational features, then the dispositional monist would have no reason to think of 'them' as being distinct properties, rather than being the very same property. In other words, a property graph which appeared symmetric would, so to speak, collapse into an asymmetric one.

The next graph constraint in Bird's system is that each node in the graph must have *at least* one manifestation relation leading away from it. This clearly has to be the case, since if a node did not bear a manifestation relation, then it could not be said to represent a disposition given that dispositions are entirely characterized by their manifestation relations.

The third constraint is that if a graph represents *fundamental* properties, each node must have *at most* one manifestation relation leading away from it. Bird's argument here is that if a property had multiple manifestations, it would be what is known as a 'multi-track' disposition, as opposed to 'single-track'. Bird suggests that multi-track properties should not be regarded as fundamental, because of their complexity (2007a, 21–4; see also Mumford 2004, 172, who suggests that the properties in fundamental particle physics should turn out to be single-track dispositions). Briefly, Bird's argument is that the ascription of a multi-track disposition (such as that of being able to speak French) is in general equivalent to the ascription of a conjunction of single-track dispositions (one of which, in the speaking French case, will be, say, the disposition to answer a specific question in a specific way). Given that these single-track dispositions are more basic, it is those that come closer to being fundamental. It may of course be that there are properties, especially in the special sciences, which are thoroughly multi-track, and if this is the case then the single-manifestation constraint will obviously not apply to graphs representing those properties. It is worth pointing out, however, that if something like physical reductionism is true, the fundamental property graphs will be of primary importance, since the higher-level multi-track graphs will be derivable from them. For this reason, it is important to consider how the fundamentality constraint can be satisfied, as we will later on.

The final constraint offered by Bird, which has been mentioned already, is that each node in a property graph should also stand in a relation to some 'stimulus' property, as well as a manifestation property. This is because a dispositional property is not only a property for a certain manifestation, '…but is also essentially a disposition to do something in response to something else, the stimulus' (2007b, 532). Therefore, if our graphs are to reveal the complete nature of a property, relations to stimulus properties must be added to the graph-theoretic framework, in the way highlighted earlier in this section.

It may be objected at this point that it is a mistake to think of there being stimulus properties, because the stimulus for a thing's disposition is more naturally described as a concrete state of affairs or event, which involves *particulars* (which bear the dispositions in question) being in contact with certain stimulating partners. When metaphysicians speak of 'stimulus conditions', for example, it is this kind of state of affairs that they typically have in mind. In the case of a charged particle manifesting acceleration, the stimulus condition will be, for example, the state of affairs of the particle being in contact with the electro-static field. Why, then, does Bird think that the notion of a stimulus *property* also has an important role to play? At this point, it is important to recall that Bird's graphs, which involve the stimulus properties, represent *second-order* structures. These second-order structures, which involve the abstract ontological dependences between the properties *themselves*, need to be clearly distinguished from the concrete events involving things-bearing-properties, which stimulus conditions are about. Moreover, on the picture under consideration the second-order structures, represented by the graphs, are explanatorily prior to the stimulus conditions concerning particulars, thus serving to explain why these stimulus conditions are as they are. Let us return to the charged particle case to illustrate. How is the nature of the stimulus condition for a particle's property of being charged to be explained? An explanation available to those who accept the Bird-type framework is this. As well as being essentially related to a certain manifestation, the property of being charged is essentially related via the second-order (internal) stimulus relation to a stimulus property, or perhaps multiple stimulus properties depending on whether charge is fundamental. Because of this, if the property of being charged is instantiated in a particular, the concrete manifestation of that property can only be brought about insofar as there is an involvement of another particular instantiating the relevant stimulus property. The reason, then, why a particle's being in contact with an electro-static field prompts the acceleration of the particle is that an instance of the appropriate stimulus property – had by the field in this case – is embedded within that state of affairs.

The kind of explanatory strategy just outlined is not unique to the dispositional monist view under consideration. Structurally similar explanations are at work in the metaphysical system of D.M. Armstrong, for example. Armstrong identifies laws with *second-order* states of affairs, involving 'N' relations between properties (see Armstrong 1983, Chapter 6), just as Bird's second-order structures concern manifestation and stimulus relations between properties. On Armstrong's account, these relationships between properties then serve to explain why the causal patterns in the world are as they are.[5]

There is also a further explanatory advantage of Bird's account of stimulus relations, which Bird himself does not emphasize. The advantage in question is that the stimulus relations among properties serve to explain why more than one kind of particular is able to stimulate the manifestation of a certain property had by another. To use a macroscopic example, a hard floor, as well as a hammer, is able to trigger the manifestation of a vase's fragility when the two collide, and the reason is that a hard floor and a hammer both instantiate the relevant stimulus property: they are both rigid.

Bearing in mind the points raised in this section about Bird's stimulus properties, we might sum up the Bird-type framework by saying that stimulus properties play a dual role. Stimulus properties (along with manifestation properties) serve to fix the very identities of dispositions, in virtue of the relations at the second-order level. Moreover, these stimulus relationships also explain why the stimulus conditions for concrete cases of dispositional interaction are as they are.

To recap, then, on Bird's graph-theoretic system, four main constraints are put in place, which we may label as follows:

i) The *identity* constraint: a graph must not be susceptible to any non-trivial automorphisms.

ii) The *manifestation* constraint: each node in a graph must have at least one manifestation relation directed away from it.

iii) The *fundamentality* constraint: each node in a graph representing the *fundamental* properties (but perhaps not all graphs) must have at most one manifestation relation leading away from it.

iv) The *stimulus* constraint: each node in a graph must also bear an outgoing relation be to a stimulus property, as well as a manifestation property.

In the next section, I will now begin to critically assess this graph-theoretic system.

3. Modifying Bird's Account: The Stimulus Constraint

I now want to suggest that the nature of dispositional interaction is misrepresented by Bird's system, and this means first and foremost that the stimulus constraint must be eradicated. In light of this, I will propose a new graph-theoretic system on which Bird's basic three-place stimulus-manifestation structure is replaced with what we may call the 'mutual manifestation' structure. On the assumption that Bird's other graph-theoretic constraints are to be preserved, the mutual manifestation modification leads to two others: first, that mutual manifestation relationships of varying adicity should be allowed, and second, that graphs representing spontaneously manifesting dispositions should be allowed. These modifications bring the advantage of reconciling the mutual manifestation model with Bird's other constraints (excluding of course the stimulus constraint, which the mutual manifestation model replaces). However, we will also see that there are independent empirical reasons for accepting the aforementioned modifications, and so acceptance of them does not rely on the assumption that Bird's other constraints are ultimately correct. For that reason, I will not scrutinize the 'identity', 'manifestation' and 'fundamentality' constraints in any more detail than that provided in the last section.

Let us begin first, then, by questioning Bird's stimulus constraint. As we saw in the charged particle example above, it seems Bird is right to acknowledge that a disposition's manifestation is in some sense dependent on the presence of a further property. There is typically a conditional aspect to dispositions, which is to say they do not give rise to their manifestation entirely of their own accord. It is noticeable, however, that in Bird's structures, the manifestation property to which a disposition is related is generally *not* also classed as the manifestation of the stimulus property; the manifestations of a disposition and its stimulus property are taken to be different. That this is so can clearly be seen in Bird's graph in Figure 1. I do not think that this is the correct way of viewing the matter, however. Plausibly, a manifestation should be regarded as the manifestation of both the properties involved. i.e., both the disposition and what Bird calls the 'stimulus' property. I will now explain why.

Let us consider in more detail the concrete case in which a particle manifests its charge by accelerating through an electro-static force field. What is it about a field which makes it the case that a charged particle accelerates when placed within it? Again, the obvious (and only) answer, for the dispositional monist, will be that the field is able to prompt the acceleration in virtue of some property – which is to say disposition – that it has. In explaining the acceleration, it would be natural to speak of the *field's* disposition to set the particle in motion, as well as the particle's charge. Might this suggest that the manifestation event (the acceleration) is as much the manifestation of the field's dispositions as it is the particle's charge? C.B. Martin thinks so, arguing as he does that disposition manifestations are always the *mutual* manifestations of what he calls the 'reciprocal dispositions' involved (Armstrong et al. 1996, 136; see also Heil 2003, 198). According to Martin, a dissolving event, for example, is not only the manifestation of the solute's solubility, but also of the dispositions of the solvent. The dissolving event is the 'common product' (1993, 182) of reciprocal dispositions working together rather than the manifestation of just one of the dispositions involved. If this case is representative of how in general properties relate to manifestations, then clearly our second-order graph-theoretic models must be made to reflect this.

As is clear in Bird's graphs (see Figure 1, for example), he sees stimulus properties as ones which have distinct manifestations to those of the dispositions they stimulate, and so he does not accommodate the kind of mutual manifestation structure discussed. One wonders where this leaves the contribution made by the stimulus property in concrete cases, however. For example, what, in the particle case discussed, can the manifestation of the field's stimulus property be if not the acceleration event itself? What other event can the manifestation of the field's disposition be thought to consist in? It is difficult to see what event this manifestation can be identified with, if not the acceleration. For one thing, evidence suggests that the acceleration begins the very instant that the particle finds itself in the field, and so there is simply no time for the field to bring about a distinct 'stimulating' manifestation (whatever that may be) which, say, then causes the acceleration of the particle.

The mutual manifestation model is therefore supported by empirical cases. But are there any good metaphysical reasons for thinking the view should be generalized? There are, and one such argument has been presented in my 2010 (Section 5). The argument is that Martin's model is needed so that a potential regress of stimuli is avoided. The regress looms when we ask what stimulates a stimulating property. This is surely a reasonable question, especially for Bird who acknowledges that dispositions have a conditional aspect to them. But once it is acknowledged that a stimulus property may itself be dependent on a further stimulating property in order for it to do its work, one can then ask what it is that stimulates this further stimulating property, and so on, *ad infinitum*. If properties have to wait for an infinite number of concrete events before manifesting, each involving different stimulus properties, it becomes a mystery how dispositions ever get around to manifesting. The solution is to view properties as forming reciprocal groups for mutual manifestation. Thus, rather than a regress of stimulus properties, we have a mutual dependence amongst *reciprocal* dispositions. The dependence is mutual in the sense that these dispositions prompt each other when instances of them are brought together. This means that instances of disposition manifestation have to wait for only one concrete stimulus event (rather than an infinite number): the event of reciprocal dispositions coming together.[6]

In sum, there are several reasons for favoring the mutual-manifestation model of dispositional interaction. In Section 6, we will see that there are reasons for thinking that not all disposition manifestations are dependent upon the involvement of further reciprocal dispositions, in which case not all manifestations are ultimately mutual manifestations. But even so, the foregoing discussion suggests that in those cases where a manifestation *is* dependent upon the contribution of more than one disposition, the mutual manifestation model is more plausible than Bird's model. How, then, can the mutual manifestation relationships between dispositions be reflected in our graph-theoretic system? This can be done by firstly relating the reciprocal dispositions to the very same manifestation property. This means that manifestation nodes will typically have more than one incoming manifestation arc. Secondly, asymmetric 'stimulus' relations must be eradicated, because on the view being proposed none of the dispositions in a reciprocal group are privileged as being either that which is the stimulat*ing* factor, or as being that which is stimulat*ed*. All dispositions in the group are equally crucial for the manifestation, such as the disposition of the particle and the reciprocal disposition of the field in the acceleration case described above. Indeed, nothing at all like stimulus relations are needed in the modified graphs, since the arrangement of manifestation relations alone will indicate which properties are reciprocal partners: they will be the properties that are directed towards a common manifestation. Overall, then, this new view of dispositional structures is more parsimonious in terms of the kinds of entities it invokes, and this is another reason why this system may be seen to be preferable to Bird’s.

In representing these modified structures, I will add some clarity-enhancing features to help clearly distinguish the various mutual manifestations within a graph. Whilst not essential, these clarity-enhancing features will be especially helpful where larger graphs are concerned. In these larger graphs, distinct mutual manifestations will be identified using lines with different hatching, and nodes belonging in the same reciprocal group will be connected with an arrowless line (or ‘edge’). For now, however, we will focus on smaller graphs. Figure 2a below shows the basic mutual manifestation structure. We might also allow structures exemplified in Figure 2b, if we follow Bird in thinking that there can be ‘looping’ manifestation relations. Looping manifestation relations are accepted by Bird on the grounds that some dispositions appear to be reflexive. An example of a reflexive disposition, offered by Bird, is the disposition of being magnetic, the manifestation of which can involve inducing yet more magnetism (2007b, 529).

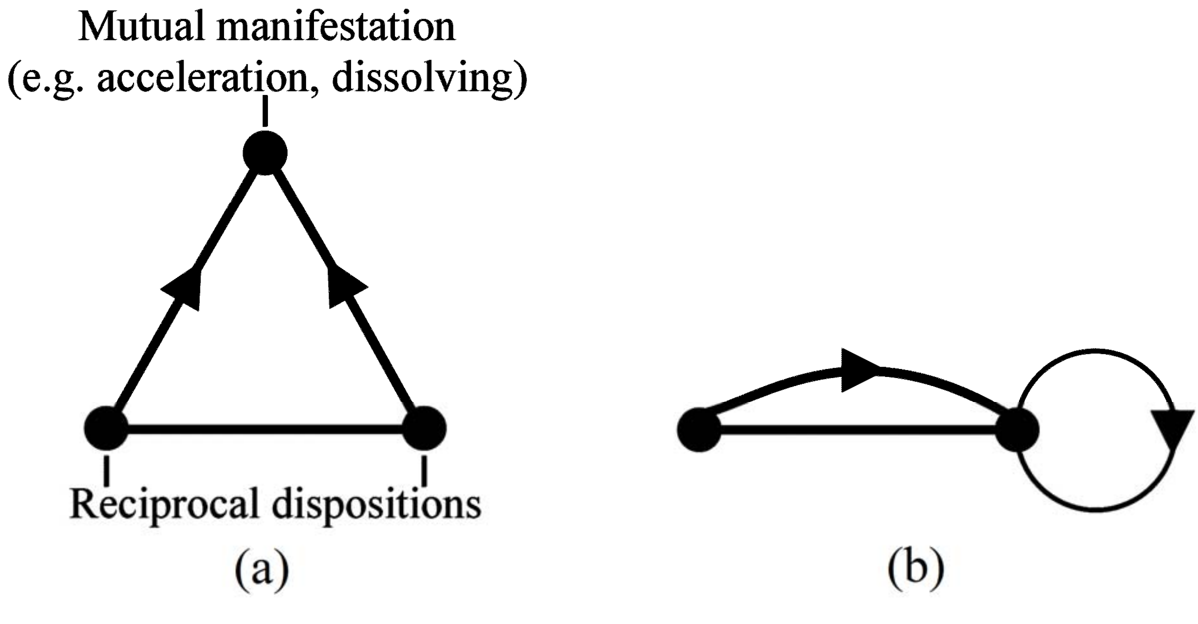

Figure 2 The Basic Mutual-Manifestation Models.

Using these new mutual manifestation structures, we may build larger graphs which represent more complex structures. The simplest cases of mutual manifestation are those involving just two reciprocal dispositions, as in Figure 2a. In Section 5, we will address potential reasons for accepting the possibility of reciprocal groups containing more than two members. We can, however, see in the six-node graph in Figure 3 that larger graphs can be built up entirely out of the simplest mutual manifestation structures (from Figure 2a). Note that this larger graph satisfies all the other graph constraints discussed earlier (excluding of course Bird's stimulus constraint, which the mutual manifestation model replaces): the graph is suitably asymmetric, and each node has a single outgoing manifestation relation, indicating that the properties represented may be fundamental in Bird's sense.

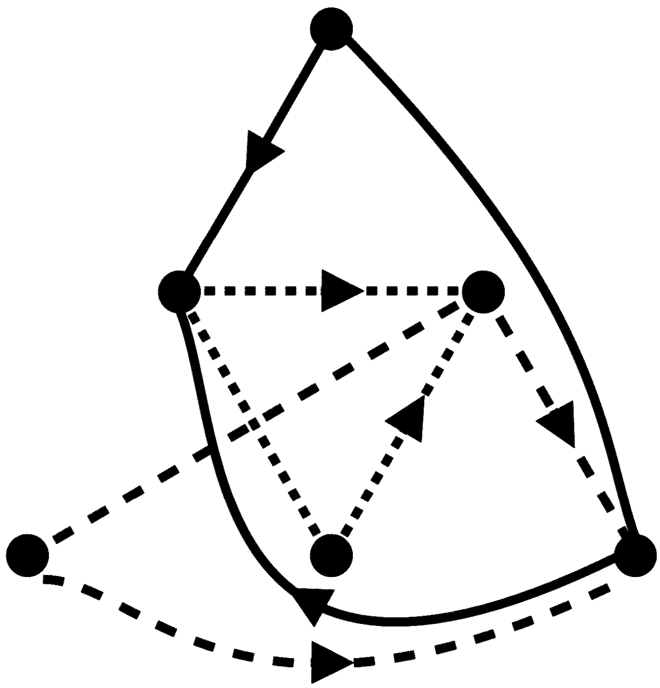

Figure 3 A Six-node Mutual-Manifestation Graph.

4. The Problem of the Three-Node Graph

It should be acknowledged that when we apply the basic mutual manifestation model to certain graphs, and try to respect the first three constraints in Bird's system, various problems do arise. Indeed, this is perhaps the reason why Bird does not endorse the kind of mutual manifestation model discussed here (although this is not an issue he addresses). However, in the remainder of this paper I will argue that the mutual manifestation model can be reconciled with these other graph-theoretic constraints once two minor and plausible modifications are accepted. Thus, Bird and his followers cannot merely reject the mutual manifestation model on the grounds that it unavoidably clashes with their prior graph-theoretic commitments. Furthermore, these two modifications will be shown to be plausible for empirical reasons independent of Bird's graph constraints, and so should be accepted even by those not convinced by Bird's other constraints.

Let us begin by considering the following basic three-node graph in Figure 4a. Firstly, this graph does not satisfy the identity constraint, since the bottom two nodes are structurally indistinguishable. Secondly, the top node has no outgoing manifestation relation, and so violates the manifestation constraint. Both of these problems can be remedied by adding a further mutual manifestation relationship to the graph, as can be seen in Figure 4b. In this modified graph, each node has an outgoing manifestation and the graph is suitably asymmetric. The problem is, however, that in this modified graph the node to the right (in Figure 4b) now has two different kinds of manifestation, and so violates Bird's fundamentality constraint. All of this suggests that on the new system as it stands, a three-node graph of properties which are fundamental in Bird's sense is not possible. This does not of course mean that the graph of Figure 4b is not suitable for representing a structure of *non*-fundamental properties. But nevertheless, the lack of resources for modelling a world containing just three fundamental properties is problematic for the dispositional monist given that there seems no obvious reason for ruling out that our world might contain just three fundamental physical properties.

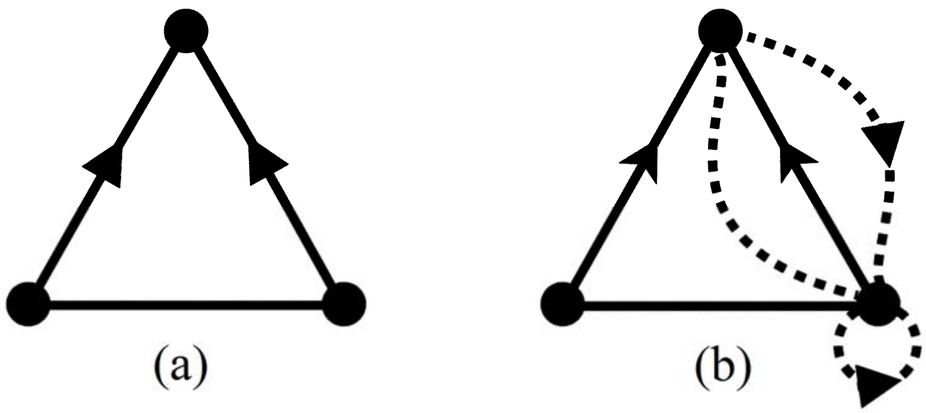

Figure 4 Problematic Three-node Mutual-Manifestation Graphs.

5. 'Odd' Graphs and the Adicity of Mutual Manifestation Relationships

Rather than abandoning any of the graph constraints discussed previously (excluding, of course, Bird's stimulus constraint, which the mutual manifestation model already replaces), the dispositional monist might think it is a small price to pay to bite the bullet and rule out the possibility that our world might contain just three fundamental natural properties. Unfortunately, however, the kind of problem facing the three-node graph of fundamental properties is going to arise again for any mutual manifestation graph containing an *odd* number of nodes. This is because, thus far, we have been dealing with the simplest case of mutual manifestation which involves just two reciprocal properties and so two manifestation relations (i.e., one outgoing from each of the two reciprocal properties). Now, if we posit *only* these simple cases of mutual manifestation, a property graph will always contain an even number of manifestation relations in total. This clearly has the consequence that at least one node in an 'odd' graph will either lack an outgoing manifestation relation or have more than one outgoing manifestation relation. More precisely, for all n, where n is an odd number of nodes, if there are ((n-1) ÷ 2) sets of mutual manifestation relationships, there will in total be (n-1) manifestation relations in the structure, and so one of the nodes is bound to lack an outgoing manifestation relation. If one remedies this by adding a further mutual manifestation relationship (so ((n+1) ÷ 2) in total), there will then be (n+1) manifestation relations, and so one of the properties will inevitably have more than one outgoing manifestation relation, making it non-fundamental on Bird's definition.

In order to save the graph constraints, one could take the bold step of accepting that a world containing an *odd* number of properties in total (what I will call an 'odd' world) simply is impossible. But since we have no independent reason to believe that 'odd' worlds are impossible, critics are likely to assert that dispositional monism leads to embarrassing, if not absurd, consequences.[7]

Fortunately, however, our framework can be straightforwardly modified so that graphs involving an odd number of properties can be constructed which do respect the mutual manifestation constraint as well as Bird's other constraints (again, excluding the stimulus constraint, which the mutual manifestation model already replaces). If we allow that some manifestations can be the manifestations of more than two reciprocal dispositions, we can allow that there could be an odd number of manifestation relations being directed towards a certain manifestation. The problem of 'odd' fundamental structures then dissolves, for if an 'odd' graph can involve an odd number of manifestation relations in total, there is no reason why each property represented cannot have a single manifestation, thereby satisfying Bird's fundamentality constraint.

Should the allowance of groups of reciprocal dispositions containing an odd number of members be seen as an ad hoc or problematic modification? I do not think so, as there seem to be actual cases of manifestation involving more than two reciprocal partners. To use a macroscopic example, the igniting of a match is plausibly a manifestation that is brought about by at least *three* distinct reciprocal dispositional partners: the flammable match, the rough surface on which it is struck, and the oxygen. Of course, this is not a case involving fundamental properties, but given that these kinds of interactions are common in everyday cases, it would not be surprising if more than two dispositions were required to bring about certain fundamental manifestations. In order to rule out in principle the possibility of fundamental manifestations which require more than two contributory factors, it seems we would need a priori reasons for doing so, and I cannot imagine what those reasons could possibly be. Moreover, from what we currently know about fundamental interactions in our world, there seem to be actual examples of manifestations which are the upshot of more than two contributing properties. Consider, for example, the force imparted upon a sub-atomic particle travelling through a (non-uniform) magnetic field. The precise nature of such a force is sensitive to at least three of the properties involved: the spin of the particle, the velocity of the particle, and the magnetic properties of the field.

It might still be objected, however, that accepting that there must be at least one ‘odd’ reciprocal group in a world containing an odd number of properties is just as worryingly ad hoc as having to deny the very possibility of ‘odd’ worlds. In response, it must be admitted that an independent reason for accepting this aspect of the solution is not being provided. However, it seems clear that as far as dispositional monism is concerned, this new constraint is far less restrictive than the alternative constraint which says there cannot be any ‘odd’ worlds at all and is much more palatable as a result. By accepting the impossibility of ‘odd’ worlds the dispositional monist cuts down the number of possible worlds by around a half, but with this new constraint in place, most of the ‘odd’ worlds which seem *prima face* to be possible are indeed possible. There are, of course, still constraints on how ‘odd’ worlds can be structured, but that is equally the case with the dispositional monists’ ‘even’ worlds. Moreover, the constraint I have introduced concerning the ‘odd’ worlds is not a particularly onerous one. Where the number of odd properties is relatively high, there will be many graph permutations for fundamental properties such that each property involved has a single manifestation. There will be successful permutations, for example, on which there is just one ‘odd’ group of reciprocal dispositions, or there may be several such groups. And those groups may contain three, five, seven, or any odd number of members.

6. The Three-Node Graph Again: Spontaneously Manifesting Dispositions

Unfortunately, while allowance of mutual manifestation relationships of varying adicity does allow some acceptable ‘odd’ property graphs to be constructed, this modification still does not help with the three node case. If we ensure that such a graph respects the manifestation and fundamentality constraints, we are left with the graph in Figure 5. Clearly, the identity constraint is violated, since the bottom two nodes are relationally indistinguishable.

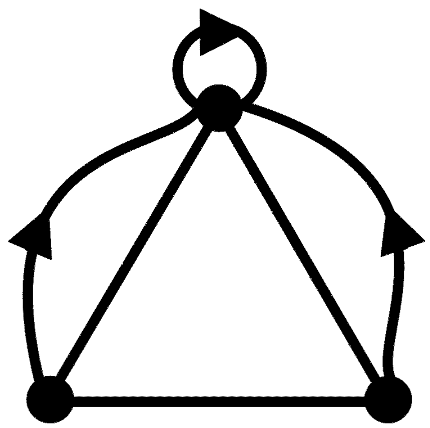

Figure 5 A Three-node Mutual-Manifestation Graph Violating the Identity Constraint.

Again, if we respect the mutual manifestation model I am proposing, we seem to be faced with the choice of either giving up on a plausible graph constraint – the identity constraint in this case – or accepting that a world containing just three fundamental properties (in Bird’s sense) is impossible. Fortunately, however, this situation can be straightforwardly avoided by the introduction of a further plausible modification. In order to add asymmetry to the original three-node graph in Figure 4a, all we need to do is to allow one of the nodes to be the manifestation of a single property only. In other words, the property which is directed towards the manifestation in question must not enter into any reciprocal relationships. Unlike typical dispositions, this kind of disposition would be able to manifest without the aid of a further reciprocal property. Such a property can be modelled in a simple way using a single directed arc: see Figure 6a. Adding a relation of this kind to our original three-node graph leaves us with the graph in Figure 6b. Clearly, this graph (Figure 6b) is apt for representing a world involving just three fundamental properties as Bird understands them: each node has a single outgoing manifestation relation and the graph is asymmetric.[8]

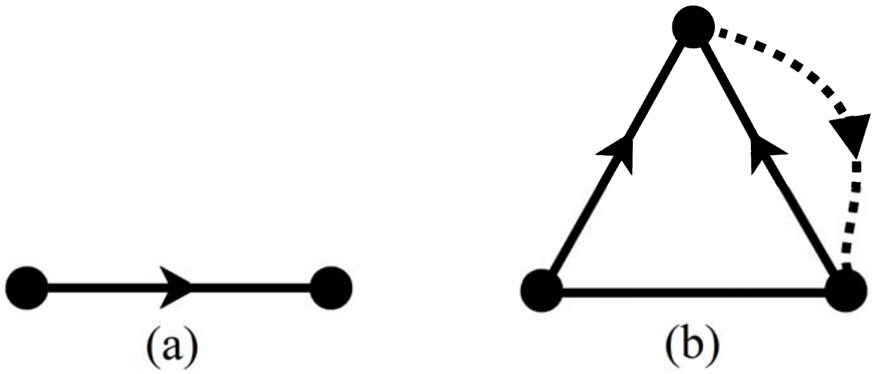

Figure 6 The Basic Spontaneous Manifestation Model (a) and an Acceptable Three-node Graph Involving a Spontaneous Manifestation Relation (b).

We might call these dispositions which manifest of their own accord 'spontaneously manifesting' dispositions. Bird does not mention such dispositions when outlining his graph-theoretic system, but allowance of such dispositions should not be thought to be ad hoc or problematic. For one thing, there is empirical evidence that there are spontaneously manifesting properties in our own world, suggesting that Martin is hasty in his apparent suggestion that disposition manifestation *always* involves reciprocity (1993, 182). An example is that of a particle's disposition to radio-actively decay, which as far as we know may manifest entirely of its own accord i.e., without requiring the contribution of something else. It is because of cases like this that Heil, who advocates the mutual manifestation model in most cases, does not claim that *all* dispositions mutually manifest with reciprocal partners (2003, 198). And if it is reasonable to suppose that not *all* manifestations are cases of mutual manifestation, there is no obvious reason why the possibility of fundamental spontaneously manifesting dispositions should be ruled out. Moreover, it should also be pointed out that allowing the possibility of spontaneously manifesting dispositions brings another benefit in that it provides another resource for letting larger graphs, such as the ‘odd’ graphs discussed in the last section, satisfy the mutual manifestation constraint along with Bird’s existing constraints (again, excluding the stimulus constraint, which the mutual manifestation model replaces). If there can be combinations of mutual manifestation relationships of varying adicity and also manifestations requiring just a single spontaneous disposition, then there will be a rich variety of graphs all of which can satisfy each of the identity, manifestation and fundamentality constraints. This, importantly, allows the dispositional monists to do justice to the thought that there are numerous ways that science might discover the world to be.

To summarize, then, if Bird were to accept Heil’s view on the matter of spontaneous dispositions, as I urge he should, he could accept the mutual manifestation model I have recommended without giving up on any of the other plausible graph-theoretic constraints advocated. This is, I suggest, an attractive feature of the graph-theoretic system proposed.

7. A Final Word about Dispositions Which Are Not Manifestations of Others

It is noticeable that in my earlier six-node graph (Figure 3) four of the nodes have no manifestation relations leading *to* them from elsewhere. This means that this graph involves properties which cannot be manifested at the first-order level by any other properties in their world. In fact, all satisfactory structures on the graph-theoretic system proposed will involve at least one property that has no manifestation relation leading to it from elsewhere. It should be pointed out, however, that it is also a consequence of Bird’s system that in many structures certain properties will unavoidably lack incoming manifestation relations. For example, all satisfactory three-node structures on Bird's system will involve such properties. The following two Bird-type graphs illustrate this point (Figures 7a and 7b), since neither of the left-hand properties in these structures are the manifestations of any others (note that the graph in Figure 7a is used by Bird himself as an example of a satisfactory structure on his system (2007b, 533, in Figure 10)).

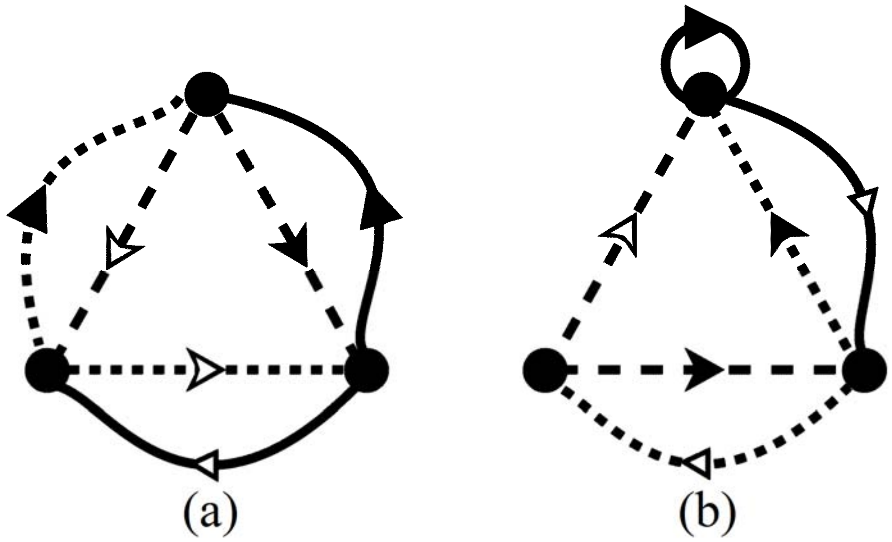

Figure 7 Examples of Bird-type Three-node Graph ((a) Reproduced Courtesy of Wiley-Blackwell).

Should the possibility of these properties be seen as a problematic consequence of dispositional monism? I do not think so. There are empirical reasons for thinking that some of the properties in our world cannot be manifested anew by properties of other kinds. For example, in physics we often speak of conserved quantities, such as mass-energy. By definition, new quantities of these properties cannot be created anew. This does not mean that a particular cannot take on a quantity of energy that it did not contain before, but it does mean that a particular can only take on a quantity of energy insofar as that energy already exists and is transferred from elsewhere. But if, in this way, *new* quantities of these properties can never be created anew, then they look like good candidates for those properties represented in a graph which are not the manifestations of any others. This clearly does not compromise their status as properties, however. As long as those properties have their own manifestations, they are just as dispositional as any other. Properties such as charge, another conserved quantity, clearly pass this test: as we saw earlier, a particle's charge may be manifested by its accelerating through a force field. In sum, then, this feature of the graph-theoretic system proposed should not be thought to be objectionable, given that properties like conserved quantities appear to exist even in our world. What the presence of these kinds of properties in all acceptable graphs might ultimately suggest is that there must always be a property (or multiple properties) in natural worlds which have been instantiated since the beginning of time, or for an infinite amount of time, and which are the entities responsible for setting the early dispositional mechanisms of the world in motion. Unfortunately, however, discussion of this thorny cosmological issue must be reserved for elsewhere.

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Notes

[1] This is an example of concrete dispositional interaction which I will continue to use during this paper. It is useful for two reasons. First, this example involves only two entities and so is a relatively simple case to deal

with. Second, it is a scientifically respectable case and so conclusions drawn from it will not be hostage to the peculiarities of macroscopic examples.

2 Property graphs could also serve a useful purpose for those who, while accepting that all properties have an irreducibly dispositional nature, deny that properties are purely dispositional. For example, this paper should be of interest to those, such as Martin (2008) and Heil (2003), who hold a two-sided view of properties. On their view, the graphs discussed in this paper could be useful as a tool for representing the features of the dispositional 'sides' of properties.

3 More precisely, according to Bird, none of the subgraphs consisting of those vertices and arcs lying on the directed *walk* (sequence of arcs) leading away from each node must be structurally identical (2007b, 531).

4 Interestingly I see evidence in Heil's work to suggest that he, as a two-sided theorist, would also embrace something like the asymmetry requirement that is involved in the identity constraint. The asymmetry requirement would have to be accepted by a two-sided theorist if it were claimed that no two distinct kinds of categorical qualities could have the same dispositional features (thus precluding graphs with symmetries). Heil seems to be pushing in this direction when he suggests that one cannot change the structural features of a thing (typically associated by the two-sided theorists with the 'categorical side') without also changing the dispositional features of that thing. In other words, no two distinct kinds of structural feature bring the same kind of dispositional side. Heil discusses the case of fragility, for example, and says that 'light bulbs, ice cubes, and kneecaps', which are all structurally different, 'shatter in very different ways'. Heil then writes: 'Try changing a fragile object qualitatively, without altering it dispositionally. The object might remain fragile, but become fragile in a different way' (2003, 116).

5 It should be noted that Armstrong's strategy of explaining causal patterns in terms of his second-order laws has not been without its critics (see for example Mellor 1991, 168). Given the structural similarity of Bird's account, it may be that similar objections will have to be answered. Unfortunately, I must postpone discussion of this general issue for another day.

6 In one place Bird does briefly acknowledge the possibility that dispositions may sometimes come in reciprocal groups (2007b, 533), but the notion of reciprocity he invokes is different to that discussed here. In the three-node graph which Bird suggests represents reciprocal properties, the properties are not directed towards the *same* kind of manifestation.

7 One might think that, equally, the dispositional monist has no independent reasons for denying the possibility of symmetrical property structures. I think, however, that there is an important difference between

the dispositional monist's denial of symmetrical worlds, and the denial of 'odd' worlds. As I suggest in Section 2, the denial of symmetrical worlds is an essential feature of the dispositional view, whereas the denial of 'odd' worlds is entailed by a combination of non-essential constraints. This means that the rejection of 'odd' worlds is avoidable in principle.

8 To avoid confusion, note that, just because the top node in Figure 6b has as its manifestation one of its reciprocal stimulus dispositions, this does not imply there are causal loops involving backwards causation at the first-order level. To emphasize again, the manifestation relations represented in the graphs are second-order relations of ontological dependence between property types. If an instance of the disposition represented by the top node manifests, the property instance manifested will be different to the property instance responsible for bringing about that disposition (though those property instances would be of the same type, according to the graph in question).

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