How to Be a Relationalist

Shamik Dasgupta

Draft of September 2018

1. Relationalism

In Dasgupta (2013) I argued that mass is fundamentally relational. On this "relationalist" view, the state of a physical system vis-a-vis mass consists at bottom just in facts about how bodies are related in mass. This is in contrast to the "absolutist" view that in addition to their mass relations there are further facts about their intrinsic masses.[1] But David Baker (manuscript) has argued that relationalism implies that classical physics is indeterministic. Baker's stated aim is just to point out this consequence, but it's not hard to imagine someone complaining that the consequence is objectionable. So a relationalist should have something to say in response.

As Baker recognizes, there are complications with some of his examples—particularly the example of escape velocity—so a relationalist might quibble over details. But that would be a distraction: I think Baker is right that relationalism leads to indeterminism. I think it leads to a kind of non-locality too, and indeed I now believe that a host of other relationalist views to which I am sympathetic also lead to indeterminism and non-locality. Consider relationalism about *motion*, the view that all motion is motion relative to another body, as opposed to the absolutist view that there are extra facts about whether something is "really" moving independently other bodies. This relationalist view also implies that classical physics is indeterministic and non-local —I'll argue in section 2 that this is the lesson of Newton's infamous "bucket argument". A third example is relationalism about *handedness*, the view that the fundamental facts about handedness consist in relations of congruence—that this hand is congruent with that one, incongruent with this other. This is in contrast to the absolutist view that there is a further property that distinguishes the *left*-hands from the *right*-hands. It turns out that relationalism about handedness also leads to a physics that's indeterministic and non-local.[2]

If these relationalist views lead to indeterminism and non-locality, the question is whether this a problem. Here I argue that it is not. This will involve distinguishing two senses in which a theory can be indeterministic and non-local. The relationalist views do lead to indeterminism and non-locality in *one* sense, but section 3 argues that this is a *virtue*, not a vice: indeterminism and non-locality in this sense is exactly what we should want! Indeterminism and non-locality would be a vice on a second sense of the terms, but sections 5-10 argue that relationalist views *do not* lead to indeterminism or non-locality in this second sense. My conclusion will be that with respect to the question of determinism and locality, relationalist views get things exactly right.

---

[1] In Dasgupta (2013) I called relationalism "comparativism". This is because in the case of other quantities like distance, even the absolutist agrees that the fundamental facts are relational; hence it seemed (and still seems to me) inappropriate to contrast absolutism with *relationalism*. Still, the multiplication of terms might be confusing in this paper, so here I revert to absolutism vs relationalism.

[2] For an introduction to the issue of absolutism vs relationalism about motion, see Sklar (1974), Maudlin (2012), and Dasgupta (2015). For an introduction of the issue about handedness, see Earman (1989), Pooley (2003), and Saunders (manuscript).

Determinism and locality are intimately connected to metaphysical possibility. Thus, to distinguish the two senses of determinism and locality we'll need to distinguish two species of metaphysical possibility (sections 7 and 8). This latter distinction might be of interest to modal metaphysicians regardless of its bearing on determinism and locality.

In what follows I focus on the case of handedness just because it is free of needless complications and illustrates the main ideas more perspicuously. I'll then apply my approach to case of mass at the end (section 10). I'll discuss the case of motion at times as we go along, but I leave a complete discussion of that case for another time.

What exactly is the issue of relationalism vs absolutism about handedness? Consider a pair of gloves: one right-handed, one left-handed. They are known as "incongruent counterparts". They are counterparts because they share the same intrinsic geometry: each contains a thumb and forefinger standing in the same angular relation, the same distance apart, etc. But they're incongruent insofar as there is no way of translating and rotating one glove through space in such a way that it exactly superimposes over the other. So defined, whether they're congruent depends on the structure of space: they're incongruent if space is Euclidean but not if it's a Mobius strip. I'll assume for simplicity that space is Euclidean.

Consider some gloves divided into two equivalence classes under the relation of congruence. Call one class 'left-handed' and the other 'right-handed'. The question is whether there's a further physical property, above and beyond their relations of congruence, that distinguishes members of one class from members of the other. Absolutism is the view is that there is, but this view comes in many varieties. One variety states that there's a primitive intrinsic property that all and only the left-handed gloves have. Another variety posits a pervasive oriented field, so that all and only the left-handed gloves are aligned with the field. And a third variety states that the gloves are situated in substantival space. On this view, the set of all glove-shaped regions of space can be divided into two equivalence classes under the relation of congruence; call the regions in one class the L-regions. Then the idea is that all and only the left-handed gloves are located in L-regions.[3]

By contrast, relationalism is the view that there's no physical property that distinguishes hands in one class from those in the other. The hands in one class are congruent with each other, and incongruent with hands in the other class, and that is all there is to it. The clearest version of this view is the anti-substantivalist view that physical reality consists just in material bodies standing in spatio-temporal relations to one another. Suppose, as the anti-substantivalist must, that the geometry of space—whether it is Euclidean—is fixed by (actual and/or possible) spatio-temporal relations between bodies. Then whether a pair of gloves is congruent is ultimately fixed by the spatial relations between their parts together with the geometry of space. For the relationalist, these relational facts of congruence are all the facts of handedness there are.[4]

---

[3] To be clear, this third variety of absolutism assumes that there is trans-world identification of regions of space. So-called "sophisticated substantivalism" denies this, but that view does not yield an absolutist view of handedness.

[4] See Brighouse (1999) and Pooley (2003) for discussion of how an anti-substantivalist is to understand relations of congruence. I will assume for the sake of argument that the relationalist has a notion of cross-temporal congruence. This entails, I think, that the relationalist must recognize *some* kind of cross-termporal spatial relation, contrary to what is sometimes known as "Leibnizian relationalism". But I bracket exactly how this is best understood.

2. Indeterminism and non-locality

I said that a relationalist physics of handedness is indeterministic and non-local. It's worth seeing why before asking whether this is a problem. Earman (1989) thought that the situation for the relationalist is in fact more dire—he argued that she can't express the physics of handedness *at all*. But I'll argue that Earman over-stated his case: the relationalist has a well-defined physics, it's just indeterministic and non-local.

Earman's argument starts from the observed fact that some things behave differently depending on whether they're left- or right-handed. His examples include neutral hyperons and the cobalt atoms, but to keep things simple I'll work with a fictional example drawn from Pooley (2003). Imagine we discover that the components of matter are not little billiard balls or point-particles or strings, but *little hand-shaped things*. Call them handrons, and imagine that some are left- and others right-handed, and imagine they move around and collide in accordance with deterministic laws of motion. Suppose further that they come in two colors, red and green, and suppose we see that they sometimes change color when they collide. Looking closer, we see that it's all and only the *left-handrons* that change color. These observations confirm the following "First Law" of handrons:

(F) Whenever a handron collides with another, it changes color iff it is left-handed.

Earman's idea is that this would refute relationalism: since left- and right-handed handrons behave differently, there must be some real difference between them. As he put it, the relationalist 'does not have the analytic resources for expressing' a law like (F) (1989, p. 148).

It will help to compare this with Newton's analogous bucket argument against relationalism about *motion*. Newton observed that bodies behave differently depending on their state of rotational motion: water in a bucket sloshes up the side *if it's spinning* but stays flat if not. He argued that the difference is not whether the water is spinning *relative to the bucket*, or *relative to the laboratory*, but whether it is spinning *absolutely*; that is, independently of its motion relative to other bodies. Thus, observations of water in buckets confirm a theory that appeals to absolute acceleration, a theory that a relationalist "lacks the analytical resources to express", as Earman might put it.[5]

But both objections are too quick, for in each case the relationalist can offer an alternative physical theory of the phenomena that she *does* have the analytic resources to express. In the case of motion, Mach took this approach when he proposed that water sloshes up the side of a bucket when it spins *relative to the fixed stars*.[6] The general approach here is to choose some body (or bodies) and say that water sloshes up the bucket when it spins relative to *it* (or *them*). One could take the same approach in the case of handedness. Suppose that a particular handron was observed to change color upon collision. Call it 'Changy'. Then a relationalist could offer the following "Machian" alternative to (F):

(F-Machian) Whenever a handron collides with another, it changes color iff it is congruent with Changy.

---

[5] Admittedly, Newton's text can be read in a number of ways; my summary is just one reading. For more on the bucket argument see Sklar (1974, chapter 3), Maudlin (2012), and Dasgupta (2015).

[6] At least, this is the view typically attributed to Mach; I won't comment on whether this interpretation is accurate.

Still, these Machian theories are unattractive. Some object to Mach's theory of motion on the grounds that he never developed it with a precision to rival Newton's. Others might object that fundamental physics should not make reference to particular entities like Changy or the fixed stars. But let me emphasize a third objection, which is that these Machian theories fly in the face of scientific practice. If our basic theory of motion were Mach's, we could never use it to model hypothetical physical systems in which the fixed stars do not exist. And yet scientists do this with physical theories all the time. Just remember high-school physics problems in which you predict the behavior of a harmonic oscillator: *on the face of it*, you're reasoning about a hypothetical physical system containing *just* an oscillator. More seriously, cosmologists routinely model counterfactual scenarios in which heavy elements, and hence the fixed stars, never form. The same goes for any Machian theory formulated with reference to some special entity like Changy: the theory can't be used to model counterfactual systems in which the special entity doesn't exist.

Is this so bad? Being a positivist, Mach may not have cared whether his theory can model far-out counterfactual scenarios. Still, it would be nice to avoid the problem if we can. In the case of handedness this is straightforward. Perhaps the relationalist can't say that the handrons that change color are all *left*-handed. But she *can* say that they're all congruent with one another, and incongruent with those that don't change color. Thus, as Pooley (2003) and Saunders (2007) point out, she can offer the following "minimalist" theory of handrons:

(F-Minimalist) (i) If x and y are congruent handrons, then x changes color on collision iff y does too.
(ii) If x and y are incongruent handrons, then x changes color on collision iff y does not.

Unlike (F-Machian), (F-Minimalist) is not tied to any particular body and so can be used to model counterfactual systems that don't contain Changy.

Sklar (1974) proposed an analogous minimalist theory in response to Newton's bucket argument. True, the relationalist cannot say that flat bodies of water are *absolutely* unaccelerated. But she can say that they're all unaccelerated relative to one another, and accelerated relative to water that goes concave. Sklar suggested that the relationalist simply offer *that* as her "minimalist" law of motion. As he put it, the law would state '(1) that objects in relative motion vary in the inertial forces they suffer and that (2) objects in uniform motion with respect to one another suffer similar inertial forces' (p. 230).[7] On this view, the water in Newton's bucket goes concave because it's unaccelerated relative to other concave bodies of water. This minimalist theory stands to Newton's theory just as (F-Minimalist) stands to (F). Unlike Mach's theory, it is not tied to any particular body and so can model counterfactual systems in which the fixed stars don't exist.[8]

---

[7] Note that by 'relative motion' he means relative *acceleration*. Obviously this is just a rough gloss of what should ultimately be expressed with mathematical precision, but the kind of theory Sklar has in mind is clear enough.

[8] Sklar (1974) is often said to have responded to the bucket argument with an *absolutist* theory that posits a primitive property of absolute acceleration. This is partly true; see his discussion on pp. 230-1. But strangely, his discussion slurs together that absolutist theory with the minimalist theory described in the text, and the subsequent literature latched onto to the former at the expense of the latter. This is unfortunate, for I find his minimalist proposal far more intriguing.

If there's an objection to these relationalist views, then, it's not that they have *no* physical theory of the phenomena—they have the minimalist theories just described. Still, it turns out that these theories are indeterministic and non-local in a way that the original theories were not.

To see why (F-Minimalist) is indeterministic, consider a world containing just two left-handrons about to collide. Will they change color? (F) implies that they will. But (F-minimalist) does not, it just implies that either *both* or *neither* will change color. Hence there are two possible futures consistent with (F-minimalist)—the mark of indeterminism.

I said that the world contains two *left*-handrons, but can a relationalist legitimately describe counterfactual worlds in terms of 'left'? Perhaps not; we will discuss this later. But for now it doesn't matter, for we may instead describe it as a world containing two *congruent* handrons about to collide. For the relationalist this is a complete description of the world vis-a-vis handedness. And (F-Minimalist) is still consistent with two possible futures, one in which both change color and one in which neither do. The absolutist avoids the problem because he distinguishes *two* worlds that fit this description: one in which the handrons have that physical property that (on his view) distinguishes the left-handrons, and another in which they don't. And the absolutist reads (F) as stating that handrons change color if and only if they have that property. (F) then implies that the handrons will change color in the first world but not the second, so in each world there is only one possible future.

I've been assuming the following standard definition of determinism:

> A theory is *deterministic* iff any two metaphysically possible worlds in which it obtains, and which agree at one time, agree at all times.[9]

The point is that the absolutist's physics satisfies this definition while the relationalist's physics does not.[10] Note that the indeterminism here is unusual. It is not that (F-minimalist) is stochastic, assigning probabilities to possible futures. It just stays silent on the matter. Say that a theory is *complete* iff it is deterministic or assigns a probability to each possible future given the state of the world state at a time. Then the point here is that (F-minimalist) is incomplete.[11]

What about the claim that (F-Minimalist) is non-local? Well, suppose that a handron is about to collide. Will it change color? According to (F-Minimalist), this depends on the results of other collision events which may occur thousands of miles away. So, as Pooley (2003) noted, whether

---

[9] See Earman (1986) for definitions along these lines. His definitions quantify over *physically* possible worlds; I assume for now that these are metaphysically possible worlds in which the actual laws obtain. Earman and others have argued that this definition must be refined, but the issues they raise are not relevant for our purposes.

[10] I'm sacrificing precision for the sake of brevity. Even as the absolutist interprets it, (F) on it's own isn't deterministic because it doesn't determine anything about how the handrons move. More accurately, then, the claim is that the conjunction of (F) *and the laws of motion that we're assuming to be deterministic vis a viz motion* is a deterministic theory, while the result of replacing (F) with (F-minimalist) is not. But I'll bracket this complication for brevity in the text.

[11] Compare the "Hole" argument, which purports to show that substantivalism renders General Relativity indeterministic. In that case too the indeterminism is incompleteness, not stochasticity. See Brighouse (1994) for some of the issues involved there. Of course, (F-Minimalist) yields implications about all collision events when conjoined with information about a single collision event, for example that Changy changed color. But that conjunction is just (F-Machian).

it changes color is a function not of its local environment but of its relation to potentially far-off events—the mark of non-locality. By contrast, the absolutist's physics is local in this respect. For according to (F), whether a handron changes color depends on whether it's left-handed, and for the absolutist this depends on whether it possesses the physical property that distinguishes the left-handrons. And on all the absolutist views surveyed earlier, this is a function of its local environment such as whether it's aligned with the oriented field—at any rate, it doesn't depend on its relation to far off collision events. Later I'll be more precise about what non-locality amounts to, but for now this gloss will do.

The upshot is that the relationalist's minimalist physics of handrons is indeterministic and non-local in a way that the absolutist's physics is not. The same goes in the case of motion. Given a world with just two buckets of water at rest relative to one another, Sklar's minimalist theory does not determine whether the water in either bucket will slosh up the side. All it says is that either both will remain flat or both will go concave, but it does not determine which (indeterminism). And whether a body of water goes concave depends on its motion relative to other, perhaps far-off, bodies of water (non-locality).

This, I suggest, is the real moral of Newton's bucket argument and Earman's analogous argument about handedness. Properly understood, the argument in each case is *not* that the relationalist can provide no physical theory of the phenomena whatsoever. Rather, it's that the relationalist's best theory turns out to be indeterministic (in the sense of being incomplete) and non-local in a way that the absolutist's theory is not.[12]

3. Turning the tables

The question now is whether this is a problem. The consensus seems to be that it is; that completeness and locality are weighty, perhaps nonnegotiable, constraints on an adequate physical theory.[13] For example, having noted that (F-Minimalist) is non-local, Pooley (2003) immediately concludes that this is a serious strike against relationalism. But I think this consensus gets things exactly back to front: the incompleteness and non-locality is a *virtue* of the relationalist's physics, not a vice!

For why think that an adequate physics must be complete and local? Here we must distinguish apriori from empirical reasons. In the first case, the idea is that completeness and locality can be established as theoretical constraints independently of observation. For example, one might argue on apriori grounds for an anti-Human view of laws on which they "govern" events, and then argue that they can't govern if they're incomplete or non-local. Or one might claim that a preference for complete and local laws is a primitive epistemic norm governing theory choice.

But whatever the details, this apriori approach isn't promising. The history of physics—in particular the history of geometry—shows that we shouldn't put much weight on apriori

---

[12] The dialectic is a little different in the case of the physics of cobalt atoms that Earman discussed. In that case, the absolutist theory he starts with is a quantum theory and hence is indeterministic anyway (at least, on some interpretations). But then the current point is that its minimalist correlate would introduce a further degree of indeterminism in the manner of incompleteness.

[13] Skow (2007) is explicit about this desidera, and notes that it is shared by theorists of many different kinds, including relationalists such as Barbour (1999).

principles to the effect that the world has this or that spatiotemporal or causal structure. Conflicting with such “principles” is not such a big deal.

It would be a much bigger deal, in my view, if completeness and locality are *empirical findings*, principles that constrain an adequate physics *because of how things look*. If handrons are *seen* to behave deterministically and relationalism implies that they do not, for example, then relationalism would be disconfirmed by observation.

And on the face of it, handrons *were* observed to behave deterministically. When our fictional scientists observed handrons colliding, we said, they didn’t just see 80% of the left-handrons changing color. No, exactly 100% of the observed left-handrons changed color upon collision, and exactly 100% of the observed right-handrons did not. It was on the basis of *this* observation that they proposed the deterministic theory (F), rather than a stochastic theory like

(F*) When a left-hadron collides with another, there is an 80% chance that it changes color.

This is not an *apriori* expectation that the process is deterministic, but an *observation* that it looks to be that way.

The same could be said in the case of motion. Why is it a problem that Sklar’s minimalist theory of motion is indeterministic? Not because we know apriori that the laws of motion are deterministic, the empirical objection goes, but because when we observed water in buckets we saw that *precisely 100% of spinning bodies of water* went concave. Thus it’s an observed fact that water behaves in the deterministic fashion described by Newton’s theory. Sklar’s minimalist theory, on which water does *not* behave deterministically, therefore flies against an empirical finding.

This then would be an empirical objection to relationalism: it’s an *observed fact* that handrons and water behave in a deterministic fashion, yet relationalism can’t account for this. But what exactly is the observed fact? Here we must take care. To be sure, the absolutist’s theory of handrons is deterministic and local; but did we observe handrons behaving in accordance with *that theory*? We did not. For let us be clear about its content. The absolutist interprets ‘left’ as referring to that physical property L that distinguishes left- from right-handrons, and for concreteness let’s suppose that L is the property of being aligned with some oriented field. So interpreted, (F) states that the handrons that change color are those that are aligned with the field. This theory is indeed deterministic and local, *but our observations did not confirm this theory*. We never observed that the handrons that changed color were all aligned with some field. After all, everything would look (and smell, and taste) exactly the same in a mirror world that differs only in that every handron is flipped from left to right and versa-versa; that is, a world in which the handrons that change color are all *anti-aligned* with the field and the ones that *don’t* change color are all aligned. What we saw is no reason to think that we live in one world over its flipped cousin. All we really observed are the relational facts common to both worlds, namely that the handrons that changed color were all congruent *with one another*. This confirms (F-Minimalist) but does nothing to confirm the absolutist’s interpretation of (F)![14]

[14] One might suggest that observation at least provides reason to believe that *there exists* a field, such that the handrons that change color are either all aligned or anti-aligned with it. The idea might be that this theory better explains the observations than (F-Minimalist), and so is justified on the basis of inference to the best explanation. But even if so, this theory is indeterministic and non-local in just the same way that (F-Minimalist) is. Thus, the point remains that *the theory justified by observation*, whatever it is, is indeterministic and non-local.

Sklar made this point when discussing his minimalist theory of motion. He emphasized that we never directly observe whether a body of water is spinning in any *absolute* sense; we just observe (i) whether it goes concave, and (ii) its state of motion relative to other bodies (Sklar 1974, p. 230). Everything would look (and smell, and taste) exactly the same in a world in which water stays flat when it is *spinning at some absolute rate* and goes concave when it is spinning relative to that absolute rate. Thus, Sklar claimed, his minimalist theory of motion, not the absolutist's theory, is exactly what is confirmed by observation. I'm just making the same point in the case of handedness.

It follows that the tables are turned: it's the relationalist's physics, not the absolutist's, that gets things right with regards to observations of determinism and locality! Sure, the relationalist's theory is indeterministic and non-local, *but such a theory is precisely what observation confirms*. If anything, it's the absolutist who has the problem here, proposing a theory that's not confirmed by the evidence.

If this is surprising, it might be because we always observe subsystems of the universe, not the entire universe itself. If I see a handron *h* about to collide and I know it's congruent with another handron that changed color, then (F-Minimalism) *plus my background knowledge* implies that *h* will change color. Likewise, if I observe a single bucket of water and I know that it's at rest relative to another bucket of water that remained flat, then Sklar's minimalist law *plus my background knowledge* implies that the water will remain flat. This gives the *appearance* of determinism: the behavior of any observed subsystem is indeed determined by the laws *and how the subsystem relates to the outside world*. Nonetheless, observation does not confirm that *the universe as a whole* is governed by the deterministic and local theory of the absolutist.

So far, then, it is the *relationalist*, not the absolutist, who has the upper hand.

4. Determinism in practice

Still, there remains something right about the empirical objection. Our fictional scientists *did* find that 100% of the observed left-handrons change color upon collision. Those observations *did* confirm (F) rather than (F*), and (F) *does* look deterministic insofar as it states that *every* left-handron *will* change color upon collision. In these respects the empirical objection was exactly right. All we've just seen is that observation doesn't confirm (F) *as the absolutist interprets it*. But the question remains what interpretation *is* confirmed, and in particular whether the relationalist can make sense of it.

The point here is that practicing scientists use 'left' and 'right' to express observation and theories like (F), and they then reason with such theories in a deterministic and local manner that I'll soon describe. The relationalist must therefore offer some account of what this practice amounts to. And one might worry that she can't; that this practice would make no sense if the world is, as the relationalist insists, indeterministic and non-local. This yields a third objection to relationalism. It's not that completeness and locality are mandated on apriori grounds, nor is it that handrons are observed to behave in the deterministic and local manner described by the absolutist. Rather, the objection is that it's part of *actual scientific practice* to express the First Law as (F) and reason with it as if it were deterministic and local, yet the relationalist can't make sense of this.

Of course, this is fictional: *our* actual scientists obviously don't talk of handrons! But I'm using the fiction of handrons to represent the physics of chiral objects like cobalt atoms, and the point is that the latter uses 'left' and 'right' (or cognates) to formulate theories and reason with them as the absolutist would predict. We must therefore imagine that our fictional physicists do the same. The same goes in the case of mass and motion: practicing scientists develop theories they write down with *seemingly* absolutist language and reason with them in *seemingly* absolutist ways. Baker's case of escape velocity is an example of this practice in the case of mass, as I'll discuss in section 10. The question in all cases is whether the relationalist can make any sense of this practice. To my mind this is the real challenge facing relationalism; the rest of the paper is an attempt to address it.

Let me set out what the practice is. Firstly, it involves using 'left' and 'right' to record observations of handrons. Physicists investigating cobalt atoms don't limit themselves to talk of congruence; they routinely use 'left-handed' and 'right-handed' (or mathematical cognates) to sort the atoms. Thus, we must imagine that our fictional physicists record their observations by writing statements like

> This *left*-handron changed color.
> This *right*-handron did not.

Second, it involves taking these statements to confirm a theory they write down as:

(F) Whenever a handron collides with another, it changes color iff it is *left*-handed.

Again, practicing physicists don't hesitate to use such language (or cognates) when expressing theories of cobalt atoms, so we must imagine that our fictional physicists do the same.

Finally, the practice includes *reasoning with (F) as if it were deterministic and local*; I'll focus on determinism for now. To illustrate, consider how (F) would be used to predict actual events. Imagine a fictional physicist teaching a student about (F), and suppose they come across a left-handron about to collide. Sensing a teachable moment, the professor sets a pop quiz:

> Question 1: According to (F), will this left-handron change color?

The right answer, of course, is that it will; that given (F) it *must* change color; that (F) *rules out* any other possible outcome. The professor should give this answer full marks. But this is to reason *deterministically* with (F). To emphasize the point, just imagine the professor had asked what will happen according to (F*). In that case the correct answer is that the handron will *probably* change color but *might not*; that (F*) leaves open *both possibilities*. Thus our physicists reason differently with (F) and (F*); only with the former do they reason deterministically.

The same goes when reasoning about *hypothetical* events. Imagine our fictional professor setting another pop quiz:

> Question 2: Consider a possible world in which there are just two *left*-handrons about to collide. According to (F), what will happen?

Again, the right answer is that both will change color; that (F) does not leave open any other possibility. Once again, this is to reason with (F) *deterministically*. The professor may then set a third pop quiz:

> Question 3: Consider a possible world in which there are just two *right*-handrons about to collide. According to (F), what will happen?

This time, the students can easily calculate that neither will change color; that according to (F) this is the *only* possible outcome. Yet again, this is paradigmatic deterministic reasoning.

Questions 1-3 are known as "initial value problems": one is given the initial state of a hypothetical physical system and is asked to solve for what happens. Note that in these problems the initial states are characterized in terms of 'left' and 'right'. Note also that left and right are treated as an independent variable, something whose initial value can be set independently of other quantities so that the effects of each value can be investigated—witness how Questions 2 and 3 differ only in a uniform switch of this value. The point is that initial value problems like these are standard in actual physics: the initial state of some cobalt atoms will be characterized in terms of 'left' and 'right' (or cognates), and a theory expressed in such terms is used to solve for what happens.

The question is whether the relationalist can make sense of this practice. Of course, she'll regard this talk of 'left' and 'right' as non-fundamental—fundamentally speaking the only truths about handedness are truths about congruence. But to account for scientific practice she must make sense of the talk nonetheless. What could 'left' and 'right' *mean* such that we can reason about initial value problems in the deterministic manner just described? And how is this deterministic reasoning consistent with her view that *fundamentally speaking*—under the hood as it were—handrons behave in indeterministically as described by (F-Minimalist)?

It's not clear what the relationalist can say. There are two worries here. The first is whether she can legitimately *characterize* problems like Questions 2 and 3 in terms of 'left' and 'right'. Suppose that the only meaning the relationalist could attach to 'left' is to treat '*x* is left-handed' as synonymous with '*x* is congruent with S', where S is some standard object like Changy, or a set of objects like hands on our heart-side or physical particles of some kind; and conversely for 'right'. On this semantics she can meaningfully describe *actual* handrons like the one in Question 1 as left- or right-handed: they are being described as congruent or incongruent with S. But this semantics is unable to account for the practice of characterizing the *counterfactual* handrons in Questions 2 and 3 in terms of left and right. For the standard object(s) S do not exist in the worlds described by Questions 2 and 3, and so on this semantics it cannot be true that those worlds contain *left*- or *right*-handrons.[15] More generally, the worry is that relationalism implies

[15] This is, in effect, our objection to the Machian theory from section 2. For if the relationalist defines 'left' as 'congruent with Changy', then in her mouth the theory (F) becomes synonymous with (F-Machian). And as we saw, this theory makes no predictions about worlds in which Changy does not exist.

Incommensurability: There is a class C of metaphysically possible worlds such that, for any possible world W in C, and any handron *x* in W, there is no fact of the matter whether *x* is left- or right-handed in W.[16]

Different specific semantics of 'left' will differ on what the class C is, but the worry is that *any* relationalist semantics will entail that it is non-empty and includes worlds like those of Questions 2 and 3. And if the handrons in Question 2 can't be said to be *left*-handed—if all we can say is that they are congruent—then (F) won't entail that they'll change color and our deterministic reasoning falls apart.

But put this aside—suppose the relationalist can legitimately characterize the world in Question 2 as containing two *left* handrons. The second worry is whether she could then characterize the world in Question 3 differently, as containing two *right* hands. For the two worlds agree on all facts about congruence, and surely—the objection goes—relationalism implies that any two worlds agreeing on all facts about congruence cannot disagree on any further facts about handedness precisely because on her view there are no further facts. Specifically, the worry is that relationalism implies

Relational Supervenience: Metaphysically possible worlds agreeing on all relational matters of congruence agree on all matters of handedness.

Thus, *if* the world in Question 2 contains two *left*-handrons, Relational Supervenience implies that the world in Question 3 *also* contains two left-handrons; hence the relationalist cannot distinguish Questions 2 and 3 or say that they have different answers. She cannot, that is, make sense of the practice of treating left and right as an *independent variable* in these problems.

If this is right, the relationalist can't make sense of the use of 'left' and 'right' we see in physical practice. In effect, there's a kind of modal breakdown: thanks to Incommensurability she can't *characterize* initial value problems like Questions 2 and 3 in those terms, and thanks to Relational Supervenience she can't *distinguish* them. By contrast, the absolutist faces no such breakdown. He interprets 'left' as denoting the special physical property L that all and only the left-handrons have. There is then no problem with characterizing worlds like Questions 2 and 3 in terms of 'left' and 'right': he is characterizing the distribution of L in those worlds. And there is no problem in distinguishing the worlds: they differ in their distribution of L. And we know that (F), so interpreted, is deterministic. But the relationalist can't interpret 'left' like this—and in any case she doesn't want to since on that interpretation, we now know, (F) expresses a theory for which there is no evidence. So the question is whether she can understand this talk of 'left' and 'right' somehow else.

If not, she must bite the bullet and say that scientific practice must be revised. But I find this unacceptable—who would seriously tell their colleagues in the physics department to revise their physics of cobalt atoms?! The point here is particularly perspicuous in the case of mass. There, the analogue of 'left' and 'right' is talk of mass in kilograms (or some other unit), and the

[16] The idea that there is "no fact of the matter" as to whether a given handron is left- or right-handed in a world W can be understood in a number of ways. One way is to admit of truth-value gaps at W, and say that instances of "*x* is left-handed" and "*x* is right-handed" are neither true nor false at W. But those who dislike truth-value gaps can understand the idea differently and say all such instances are false at W. It will not matter for our purposes which version we pick (the main points can be reconstructed regardless) though I will sometimes talk as if there are truth-value gaps for simplicity.

analogue of Questions 2 and 3 are initial value problems that differ only in a uniform doubling of mass in kilograms. As I'll discuss in section 10, what Baker (manuscript) shows is that standard scientific practice distinguishes these problems and predicts a different evolution for each problem. It would be outrageous to tell one's colleagues in the physics department that this talk of kilograms must be banished. So I think the relationalist must make sense of this practice or go home.[17]

This then is the challenge. The relationalist must interpret talk of 'left' and 'right' in such a way that makes sense of the deterministic reasoning above, yet does not collapse into the absolutist's interpretation on which (F) expresses a theory for which there is no evidence.

5. Devices of coherence

In what follows I will show how the relationalist can do this. I will not argue that it is the best or only way, just that it works. I proceed in two stages. First, I'll describe how a relationalist might use the terms 'left' and 'right'. On the basis of that usage, I'll then develop a theory of metaphysical possibility that avoids the modal breakdown and thereby makes sense of the deterministic reasoning with (F) described above.

So, how might a relationalist use 'left' and 'right'? The obvious way is to define 'left' as 'congruent with Changy', or some other standard. But we know that this leads straight to Incommensurability. Thankfully, there is another way to use the terms. Let me illustrate with a fictional community of relationalists who lack the terms 'left' and 'right'. They have only a 2-place relational predicate 'x is congruent with y' with which to talk about handedness. They wish to introduce 1-place predicates to help them store and communicate information about congruence more efficiently. To this end, they introduce two new marks, # and *. Their idea is to use these marks in such a way that if two hands are given the same mark this means they are congruent, while marking them differently means that they are incongruent. More precisely, they stipulate that the marks are monadic predicates that are governed by the following three rules of inference:

(R1)	(R2)	(R3)
<u>*x* is #, *y* is #</u>	<u>*x* is *, *y* is *.</u>	<u>*x* is #, *y* is *.</u>
Therefore, *x* and *y* are congruent.	Therefore, *x* and *y* are congruent.	Therefore, *x* and *y* are incongruent.

But they stipulate nothing else. Note that these are exit-rules; there are no intro-rules that specify sufficient conditions for concluding (say) that *x* is #. Thus, they have not given explicit definitions of the predicates in terms of standard reference bodies.

Still, this is enough to ground a practice that encodes information about congruence. When they first encounter a handron *h1* they can call it # or *, since either is consistent with the rules. Suppose they call it #. And suppose they then encounter a handron *h2* that is incongruent to *h1*.

---

[17] It might be thought that initial value problems like these can be interpreted as descriptions of possible *sub-systems* that exist alongside various reference points such as standard objects in Paris, laboratory equipment, and so forth, so that Incommensurability will never be a problem. But even if this is an option with *some* initial value problems, the solution clearly does not generalize. As I mentioned before, cosmologists think about initial value problems in which heavy elements, and hence our planet and all the reference points it contains, never exist.

If they call it #, then by (R1) they could infer a falsehood. So, insofar as they aim to utter things that imply truths their hand is forced: they must call it *. Thus, when a speaker uses the marks her aim is to "cohere" with other accepted uses in the community, in the sense that their combined uses yield truths about congruence via (R1)-(R3). Once their use of the marks becomes entrenched—imagine them using these marks for a few decades—there will be a clear distinction between "correct" uses that cohere and "incorrect" uses that do not. In this way, they can use # and * to communicate information about congruence.

Cohering with one's community is no easy task, especially if the community is large and dispersed. To aid coherence it helps to use a "standard glove" displayed in a public place: if each speaker ensures that she coheres with the sentence 'The standard glove is #', they will all cohere with one another. But—and this is important—they need not *define* the predicate "*x* is #" to be synonymous with '*x* is congruent to the standard glove'. The standard glove is functioning just as a practical aid to help them cohere, not as a definition (or as a reference-fixer). If they discover by surprise that all their interactions with the standard glove were subject to some massive and systematic illusion, so that the standard glove is in fact *incongruent* with the gloves they call #, they would report this discovery by saying that the standard glove is in fact *. So long as their other applications of # and * still cohere with one another, there is no need for further revision.

I think that that our words 'left' and 'right' are in all important respects like # and *. They are devices of coherence, so that our aim in uttering 'x is left-handed' is to cohere with other utterances in our linguistic community in the above sense. On this view, reference objects like the hand on our heart-side, or certain kinds of molecules, or standard gloves in Paris, do not serve to define 'left' and 'right' but are practical aids to help us cohere with one another. But the claim that *we* use 'left' and 'right' as devices of coherence is an empirical claim about us that I won't defend. Here I just make the uncontroversial claim that it is *possible* for a community of relationalists to use 'left' and 'right' this way. What I'll argue is that *if* they use the terms like this, that would explain their usage in physical practice described in the last section.

It is easy to see that it would account for the practice of describing observations like (O) and advancing theories like (F). Imagine that a community has used 'left' and 'right' as devices of coherence for generations, so that there is a clear distinction between "correct" uses that cohere and "incorrect" uses that do not. They will then recognize left-hands from right-hands in much the same way that we do, say by making an "L" shape with the hand on her heart side, or whatever other method you like to use. For them, these methods are not an attempt to determine whether a given hand satisfies a definition of 'left', but an attempt to ensure that their use of the terms cohere. So, when observing handrons they'll fill their notebooks with inscriptions like

(O) This *left*-handron changed color.
This *right*-handron did not.

And they would take these to confirm a theory they'd write down as (F). Since their use of 'left' is not tied to any particular standard object, their utterance of (F) is not equivalent to a Machian theory.

To be clear, this is not to settle all semantic questions about this practice. What proposition is expressed by (F) or the sentences in (O)? What are their truth-conditions? I haven't said, though I'll discuss this further in section 8. For now, the claim is just that a relationalist using 'left' and 'right' as devices of coherence can record her observations of handrons in these terms and will take those observations to confirm a theory she'd write down as (F).

6. Modal Correspondence

That much is straightforward. The more difficult question is whether the relationalist can make sense of the deterministic reasoning with (F) manifested in Questions 2 and 3. Here she faced the "modal breakdown". Thanks to Incommensurability she couldn't *characterize* the worlds in Questions 2 and 3 in terms of left and right, and thanks to Relational Supervenience she couldn't *distinguish* them.

We've already made *some* progress here, for if 'left' and 'right' are devices of coherence why *shouldn't* they be used to characterize those worlds? By labeling the handrons in Question 2 'left' one can't derive anything false with (R1)-(R3); all one can derive is that they're congruent![18] Thus, nothing about the rules governing the terms prohibits their application in Question 2. This is in stark contrast to the semantics on which 'left' is defined in relation to Changy, which entails that 'left' has no application to worlds in which Changy doesn't exist. It's therefore not obvious that we face Incommensurability if the terms are used as devices of coherence.

The same goes for Question 3: nothing in the rules (R1)-(R3) prohibits us from labelling those handrons as 'right'. But if we label the handrons in Question 2 as 'left' and those in Question 3 as 'right', we appear to be *distinguishing* the initial value problems after all! It's tempting to wonder, then, whether we have a solution to the problem of Relational Supervenience too.

The idea can be modeled by representing the initial value problems with pairs of the form $\langle W, f \rangle$, where W is a possible world and f is a function assigning the word 'left' to one congruence class of handrons in W and the word 'right' to the other. Even if a relationalist can't distinguish two *possible worlds* that differ only in a uniform flip of left-to-right and vice-versa, she can easily distinguish $\langle W, f_1 \rangle$ and $\langle W, f_2 \rangle$, where f_1 and f_2 differ only in flipping which congruence class is mapped to the word 'left'. Functions are cheap, as they say. Thus, while Relational Supervenience might be true of the *possible worlds*, it certainly isn't true of the pairs.

More generally, it's clear that the space of pairs $\langle W, f \rangle$ recognized by the relationalist corresponds one-one with the space of metaphysically possible worlds recognized by the absolutist. The temptation, then, is to have the relationalist mimic everything the absolutist does with possible worlds by using the pairs instead. Thus, while the absolutist interprets an initial value problem as characterizing a *possible world*, the relationalist might interpret it as characterizing a *pair* and solve it in exactly the same way. *Et voila*: we've made sense of the reasoning involved in Questions 2 and 3! Similarly with the definition of determinism which quantified over a set of indices we called "possible worlds". The absolutist will take that at face value, and we saw that (F)—as he reads it—satisfies that definition. But the relationalist might now interpret the indices as pairs, not possible worlds, and so understand a theory to be deterministic iff any two *pairs* in which it obtains and which agree at one time, agree at all times. Then (F), even in her mouth, is deterministic in this sense!

---

[18] I'm assuming that like any set of intro- or exit-rules they are only applicable within a world. After all, suppose it's an exit-rule governing 'bachelor' that from 'x is bachelor' that one can infer 'x is unmarried'. If an individual *a* is a bachelor in W, one can infer by this rule that *a* is unmarried in W but not that *a* is unmarried in a distinct world W*!

But is this legitimate? The worry is that it's just trickery; that the pairs are cheap formal objects that do no real philosophical work. For the pairs are not themselves metaphysically possible worlds, so what they represent isn't *metaphysical possibility* in the standard sense. Given what philosophers typically mean by "metaphysical possible world", there is I think no question that relationalism implies Relational Supervenience. The pairs are formal objects that make that problem go away, but the cost is that we're no longer talking about metaphysical possibility in the standard sense.

Is it a significant cost? Perhaps not, for it's an open question whether initial value problems must be understood in terms of the possible worlds of the modal metaphysician. When a high-school physics teacher gives her students initial value problems for homework, it's far from clear that she's asking them to think about "metaphysically possible worlds" in the philosopher's sense of the term! Indeed, physicists rarely use the term themselves, talking rather of "models" or "hypothetical physical systems" or "fictional situations". The same goes for the indices we quantify over in a definition of determinism: it's an open question whether they must be understood as possible worlds in the philosopher's standard sense of the term. Again, physicists typically define the notion in terms of "models", or "closed systems", or something of that ilk, and it's not obvious that these must be understood as alternative labels for what the philosopher calls a "metaphysically possible world". So there must be some lee-way to diverge from philosopher's preferred notions.

But the lee-way is not unlimited. For the pre-theoretic idea behind determinism is that a system *must* evolve in a certain way, given the laws. And it's widely agreed that this is not the logical 'must': it's not that the present state of the system and the laws *logically imply* its future state. Nor is it an epistemic 'must': it's not that *an ideal agent could infer* how the system will evolve, given complete knowledge of its initial state and the laws—this notion of "Laplacian determinism" is not of interest to contemporary philosophers of physics. Rather, the consensus is that the relevant sense of determinism involves a *metaphysical* 'must'. It's hard to say exactly what this means, but the rough idea is that metaphysical possibility is constrained not by the logical constants (logical possibility), or by states of knowledge (epistemic possibility), or by the meanings of words (conceptual possibility), but by "the world"; by the things it contains and what they're like. Thus, when a deterministic system *must* evolve in a certain way, this is due not to states of knowledge or the logical properties of a formal language or the meanings of our words, but to *the nature of the system itself*. Our definition of determinism attempts to capture this by quantifying over a set of indices, the "possible worlds". But this will succeed only if each index is a distinct possible world *in some recognizably metaphysical sense of the term*. So it's not enough to just produce formal objects like the pairs <W, *f*> and use them to define determinism, it must also be shown that they represent a genuinely metaphysical sense of possibility.

I will argue that they do. Now, obviously the kind of possibility they represent isn't what philosophers normally mean by "metaphysical possibility", for the latter creates the very problems that the former is supposed to solve. So what I'll argue is that we must distinguish two varieties of metaphysical possibility. One is the normal philosopher's sense of the term—the familiar sense in which relationalism implies Relational Supervenience. Call this "strict possibility". But I'll argue that there's another notion of metaphysical possibility, which I'll call "loose possibility", on which relationalism does *not* imply Relational Supervenience or Incommensurability. This is the notion of possibility represented by the pairs. If that's right, our hope is vindicated after all: the relationalist can legitimately use the pairs—or more accurately, the loosely possible worlds they represent—to mimic the absolutist and account for deterministic reasoning involving (F).

For this to work we must establish two things about loose possibility. First, we must show that the relationalist's conception of loose possibility accurately mimics the absolutist's conception of strict possibility. Thus, where the absolutist distinguishes two strictly possible worlds that differ only in a uniform flip of left-to-right, the relationalist must distinguish two *loosely* possible worlds that differ in the same way. More precisely:

> **Modal Correspondence Thesis:** There is a one-one correspondence between the space of *strictly* possible worlds recognized by the absolutist, and the space of *loosely* possible worlds recognized by the relationalist, that preserves all relational facts of congruence *and* facts about left and right.

Second, we must show that loose possibility really is a genuine species of metaphysical possibility. But what exactly is meant by "metaphysical" possibility? I glossed is as possibility that's constrained by "the world", rather than our concepts or states of knowledge or the logical properties of a formal language, but that's hardly precise. Still, we can sidestep the question by taking strict possibility as our fixed point. For there's no doubting that *it* is a species of metaphysical possibility—it's the paradigm case! I'll offer a theory of strict possibility on which it's understood in terms of *fundamentality*, which in turn is understood in terms of *metaphysical explanation* (section 7). I'll then distinguish a slightly different notion of metaphysical explanation and show that it yields a slightly different notion of possibility; this will be loose possibility (section 8). Since strict and loose possibility are both understood in terms of two closely related senses of explanation, that will suffice to show that each is as "metaphysical" as the other, whatever that means.[19]

7. Possibility and explanation

So let me offer a theory of strict possibility, the ordinary notion of metaphysical possibility familiar to philosophers. There isn't space to defend it fully here; my aim is just to articulate it and lend it some plausibility. The theory consists in two claims. The first is that *a strictly possible world is a way of reorganizing fundamental matters*. For example, consider a relationalist view on which fundamentally speaking there are just handrons standing in spatial relations with one another—ignore any non-spatiotemporal properties and relations. A strictly possible world, then, is a way of reorganizing the spatial relations between handrons. This explains why relationalism implies Relational Supervenience regarding the strictly possible worlds. For if a strictly possible

[19] My strategy here is structurally analogous to Boghal (forthcoming). There he distinguishes metaphysical explanation from *scientific* explanation, and he then argues that each notion yields a corresponding notion of possibility, metaphysical and scientific possibility respectively. But his notion of scientific explanation is different from the notion I'll distinguish, and hence the notions of possibility we end up with are different too. As he emphasizes, his notion of scientific explanation is explicitly *non*-metaphysical and hence his notion of scientific possibility is non-metaphysical too. Here I employ the same strategy but my aim is to distinguish two notions of possibility that I suspect would both count as metaphysical even by Boghal's lights. In Dasgupta (2013) I tried to distinguish strict from loose possibility with a different strategy. The idea was to mimic Lewis' (1986) "cheap haecceitism", where he uses counterpart theory to distinguish between two modal indices: possible worlds and possibilities. I showed that this approach can be extended to the case of mass, and if so it could be applied to the case of handedness too. But counterpart theory (of any form) now strikes me as an inadequate way of getting to grips with metaphysical possibility, so here I explore a different strategy.

world *just is* a way of spatially relating handrons, then strictly possible worlds agreeing on all relational respects are the same.

This conception of a possible world is arguably implicit throughout philosophy. Consider the physicalist view that the world is, fundamentally, just physical. It is widely presumed that this has the consequence that worlds that are physically identical, and which contain no "alien" fundamentalia, agree in all respects concerning consciousness, normativity, and so on. This is indeed a consequence of physicalism, if a world is a way of recombining fundamental matters.

This claim that a strictly possible world is a way of reorganizing fundamental matters does not imply "combinatorialism", the view that *every* reorganization is a strictly possible world. If distance-in-feet is fundamental, one reorganization of the fundamental matters would consist in x being 1 foot from y, y being 1 foot from z, and yet x being 50 feet from z in violation of triangle inequality. If you think that's impossible, you might propose that principles like triangle inequality restrict which ways of reorganizing fundamental matters are genuinely possible. I'll call these "metaphysical principles", though I won't settle what they are or if there are any. Thus, when this first claim states that a strictly possible world is a way of reorganizing fundamental matters, it means a reorganization that's consistent with the metaphysical principles (whatever they are).

This first claim connects strict possibility with fundamentality, but what is fundamentality? The second claim is that something is fundamental iff it's *unexplained* in a "metaphysical" or "constitutive" sense of the term. To illustrate, suppose that the fundamental matters just concern atoms arranged in space. Still, there are chairs; it's just that chairs are things that exist when *and because* the atoms are arranged in a certain way. The fact that there are chairs *holds in virtue of* the arrangement of the atoms; that arrangement *makes it the case that* there is a chair. This mode of explanation is not causal but "constitutive". We can be ecumenical in how we understand this notion. Perhaps it is (or tracks) a primitive relation of "grounding" between facts (Rosen 2010), or perhaps it is better analyzed in terms of dependency relations (Schaffer 2016, forthcoming), or metaphysical laws (Wilsch 2015), or unifying patterns (Kovacs manuscript). Or we might understand the explanation semantically, as reporting that "There are chairs" is made true by the arrangement of atoms.[20] Indeed for our purposes we could understand it in a deflationary manner congenial even to a logical positivist. For even a positivist can accept that John's being a bachelor holds in virtue of his being an unmarried male; she just understands this as meaning that "John is a bachelor" follows logically from "John is an unmarried male" together with the analytic definition of "bachelor".[21] All I require is that we do not understand this notion of explanation in terms of possibility. Quite the opposite: we will understand possibility in terms of this notion of explanation.

According to the second claim, then, the fundamental matters are those that are unexplained in this constitutive sense: if they obtain there's nothing in virtue of which they obtain. This understanding of fundamentality is controversial (see Wilson (2016) for objections) but I won't defend it here—my aim is just to outline this theory of strict possibility. If you like, you

[20] This is close to Sider's "metaphysical semantics" (2011, chapter 5). While Sider himself doesn't endorse this, one could in principle say that P explains Q iff the correct metaphysical semantics implies that 'Q' is true if P. But this bears considerable refinement, and of course if one wants to join me in defining fundamentality in terms of explanation, one had better not join Sider in defining metaphysical semantics in terms of fundamentality! But I will not elaborate on these issues here.

[21] See Dasgupta (2017) for various "deflationary" ways of understanding this notion of constitutive explanation.

can read this second claim as *stipulating* the sense of "fundamentality" meant in the first claim. Either way, putting the two claims together yields a theory of strict possibility in terms of explanation: a strictly possible world is a way of reorganizing unexplained matters.

One nice feature of this theory is that it explains why the space of possibilities is as broad as it is. Handrons could have been arranged differently in space, let's agree, but why? Our theory offers an answer. For there is, I think, a constitutive connection between explanation and possibility: roughly, that *if something has no explanation then it could have been otherwise*. The idea is that if there's *no reason* why something obtains—if there is nothing *making* it obtain—then it *might not have* obtained. This is why (ignoring the metaphysical principles for a moment) if you reorganize those matters for which there is no explanation, such as how handrons are arranged in space, you get a way things *could* have been; a possible world. Of course, as stated this constitutive connection between explanation and possibility is no more than an aphorism and needs considerable refinement. Still, like all good aphorisms it contains a germ of truth—enough to offer a glimpse of why it makes sense to think of a strict possibility as a reorganization of unexplained matters.[22]

Indeed, the connection between possibility and explanation goes deeper. Suppose the fundamental matters concern atoms arranged in space, and suppose that W is a world in which atoms are arranged chair-wise. Arguably, W is also a world in which there is a chair. But why? Why isn't it a world in which there's a penguin? The question is what constrains what's the case at W above and beyond the fundamental matters. One natural answer is that whatever's the case at W must *hold in virtue of* the fundamental matters at W. The existence of a chair would hold in virtue of the arrangement of atoms in W but the existence of a penguin would not; that is why W is a world in which there is a chair.

The general idea, then, is that possibility is limned by explanation. If something is constitutively explained by other matters, that constrains it from being otherwise so long as those other matters remain unchanged. But if it has no constitutive explanation then it's not so constrained and can therefore vary. To implement this more precisely we'd need a nonfactive notion of constitutive explanation on which one state of affairs, which may or may not obtain, is explicable by others, which may or may not obtain. This could be regimented with an operator

T, U,… settle that S

[22] What about the metaphysical principles themselves? Why can't *they* be otherwise? As stated our aphorism implies that, being necessary truths, they must have an explanation. But the explanans must presumably be necessary too, so do we have an infinite regress? Here is one place the aphorism needs refinement. One solution is to restrict it to matters that I have elsewhere called "substantive"; that is, matters that are "apt for being explained" in the constitutive sense. If so, then "autonomous" matters—matters that are not apt for being explained—fall outside the scope of the aphorism, and can then be necessary and true for no reason. See Dasgupta (2014b, 2016) for more on the distinction between 'substantive' and 'autonomous' truths. We can then say that the metaphysical principles, if any, are autonomous and hence also outside the scope of the aphorism. But it would detract from the main thread to refine the aphorism in detail here.

glossed as “if T, U,…, that would make it the case that S”, where this doesn’t imply that T, that U, … or that S.[23] For convenience I will sometimes abbreviate this with quantification over states of affairs, or facts, or “matters”, saying that some matters (facts, states) settle others.

Our theory, then, is that a strictly possible world is a way of reorganizing those matters that aren’t settled by anything. If those matters just concern handrons spinning in a void, then a strictly possible world W is a way of reorganizing how the handrons spin in the void. And W is a world in which there is a chair just in case the handrons in W spin in such a way that constitutes (that is, settles that there is) a chair.

8. Strict and Loose Possibility

We’ve just understood strict possibility in terms of being unexplained. But I’ll now argue that being unexplained is ambiguous. If ‘left’ and ‘right’ are devices of coherence then there’s one sense in which matters of left and right are explained and another sense in which they aren’t. The former sense yields the notion of strict possibility above, the latter yields the notion of loose possibility we’re looking for.

The key is to recognize that if ‘left’ and ‘right’ are devices of coherence then they’re not fully factual. Lee and Yalcin (manuscript) also argue for a non-factualist view about left and right; here I’ll argue that non-factualism follows from the claim that they’re devices of coherence.

By calling an expression factual I mean, roughly speaking, that its function is descriptive. The word ‘white’ is factual insofar as it is (typically) used to describe things as being white, while ‘Hooray!’ is non-factual insofar as its function is not descriptive but emotive—one uses it to express joy. Likewise, on a simple expressivist view of moral discourse, ‘good’ is non-factual insofar as it is used not to describe the item to which it’s applied but to express a pro-attitude towards it.[24]

An utterance can then be evaluated as “correct” or “right” depending on whether it fulfills its function. Since factual and non-factual expressions have different functions, this induces different standards of evaluation. Thus, an utterance of

(1) Snow is white.

is correct if, and because, snow is as (1) describes it to be; that is, if (and because) snow is white. Thus, what makes a factual utterance correct is that it is *true*. By contrast, consider an utterance of

(2) Charity is good.

---

[23] Since statements of this form help generate the space of worlds, they don’t vary in truth-value from world to world; they are just true or false simpliciter. Does this mean that they’re necessary? We could say that, but it would be misleading since their truth or falsity is prior to the worlds they generate. I prefer to think of them as “aworldly” in something akin to Fine’s (2005) sense.

[24] I just explained the factual vs non-factual distinction in terms of a word’s *function*, but some philosophers express puzzlement about the idea that words have functions. I confess that I’m puzzled about their puzzlement. Like cups and saucers, words are things we use for certain purposes; their function can be thought of as whatever we use them to do. This is not the only sense in which words have functions, but it’s a particularly unproblematic sense and is all I need here.

On the simple expressivist view, ‘good’ is used to express a pro-attitude; hence the utterance is correct if, and because, the utterer has that pro-attitude towards charity. Thus, non-factual expressions are distinctive insofar as what makes utterances containing them correct is not their *truth* but something else.[25]

Is ‘left’ factual? It would be if defined as synonymous with ‘congruent with Changy’, for its function would then be to describe things as being congruent with Changy. Thus, given a particular glove Gary, an utterance of

(3) Gary is left-handed.

would be correct if, and because, Gary is indeed congruent with Changy. The same goes for an absolutist who interprets ‘left’ as expressing that physical property L that distinguishes the left from right hands. For then the function of ‘left’ would be to describe things as having that property L, and an utterance of (3) would be correct if and because Gary has L.

But if ‘left’ is a device of coherence then it’s not factual in this sense. For one’s aim in uttering (3) is then not to describe Gary but to cohere with one’s linguistic community—to utter something which, along with other accepted applications of ‘left’ and ‘right’, would yield truths about congruence via the rules (R1)-(R3). So, what makes the utterance correct is not that it is true but that it coheres. Remember, the rules (R1)-(R3) are just exit rules; they do not define a property of being left-handed, like L, possession of which by Lefty would explain why (3) is true. Rather, the correctness of the utterance is fully explained by the fact that it coheres.

To be clear, to say that this talk is non-factual is not to deny that it’s constrained by the world. For its correctness consists in coherence, and utterances cohere iff they imply *truths about congruence* via the rules (R1)-(R3). Unlike ‘Hooray!’, then, correctness does not depend solely on one’s subjective mental state; it depends largely on the worldly facts about congruence. So this is a non-factualism of a somewhat mild stripe, but it’s non-factualism nonetheless.[26]

It follows, I suggest, that there is no constitutitve explanation of why Gary is left-handed; there is nothing about the underlying congruence facts *in virtue of which* it is left-handed. Again, things would be different if ‘left’ were defined to be synonymous with ‘congruent with Changy’. For in that case it would be natural to say that Gary is left-handed *in virtue of* being congruent with Changy. Here there is a kind of semantic transparency: that which explains why (3) is correct—namely, Gary’s being congruent with Changy—also explains why Gary is left-handed.

[25] In saying that truth *explains* the correctness of factual utterances, am I assuming an inflationary theory of truth? Strictly speaking, yes. But this is just a convenience and the main point can be put in deflationary terms. For a deflationist can agree that (1) is correct because snow is white, and so can mimic our account of factual utterances with the following scheme: if ’S' is factual then ’S’ is correct if, and because, S. There is, of course, more to say about the factual vs non-factual distinction, but the rough idea just glossed is clear enough for our purposes. For more see Gibbard (2003) and Yalcin (2012), though I stress that the distinction I’m drawing here may not coincide exactly with theirs.

[26] Moreover, note that the non-factualist need not deny that there are truths or facts of left and right in a deflated sense. If (3) is correct then it’s assertible that Gary is left-handed; hence it’s assertible that (3) is true in a disquotational sense of ‘true’ (see Field 2001). But its truth in this sense is explanatorily derivative; it doesn’t enter into the explanation of why (3) is correct.

But our examples of non-factual discourse aren't transparent in this sense. This is clear with 'Hooray!': it makes no grammatical sense to explain why Horray! But it's also true of (2) on the simple expressivist view of moral discourse. On that view, there's a constitutive explanation of *why my utterance of (2) is correct*: it is correct in virtue of the fact that I have a pro-attitude towards charity. But it's *not* part of this expressivist view that charity is good in virtue of my pro-attitude towards charity—even in *my* mouth this explanation would not be right. To think otherwise would be to confuse expressivism with a subjectivist view on which my saying 'x is good' means *that I have a pro-attitude towards x*. The same, I claim, goes with (3). There is a constitutive explanation of why my utterance of (3) is correct: it's correct because it coheres with my neighbor's utterances. But this is *not* an explanation of why Gary is left-handed. To think so would be to mistake (3) with the factual assertion *that Lefty is congruent with hands my neighbors call 'left'*. And that mischaracterizes the phenomena: when 'left' is used as a device of coherence the aim is not to describe Gary as having a certain property but to cohere with other utterances.[27]

What we see here is a distinction between a (non-trivial) explanation of *what makes an utterance of 'S' correct*, and an explanation of *what makes it the case that S*. With factual utterances they are the same precisely because correctness amounts to truth. But with non-factual utterances they are different: that which makes (3) correct—that it coheres—does *not* make it the case that Gary is left-handed.

The upshot is that if a relationalist uses 'left' and 'right' as devices of coherence then the question of whether matters of left and right are unexplained is ambiguous. On the one hand, the *correctness* of 'left' and 'right' talk is explained in terms of congruence: my utterance of (3) is correct in virtue of the fact that Gary is congruent with gloves my neighbors call 'left'. In this sense, matters of left and right *do* have a constitutive explanation in relational terms. On the other hand, there is nothing in virtue of which Gary is left-handed—in *that* sense it's a brute, unexplained matter whether Gary is left-handed. If it sounds odd to hear a relationalist saying this, remember that being left-handed is, on her view, a non-factual matter. Thus it remains the case on her view that all the *factual* matters that are unexplained (in the constitutive sense) are relational; that is what makes her view count as *relationalist*.

We can characterize the two senses of being unexplained as follows:

> It is *loosely fundamental* whether S iff nothing settles whether S.
>
> It is *strictly fundamental* whether S iff (i) nothing settles whether S and (ii) it is factual whether S.

Put in these terms, the question of absolutism vs relationalism concerns the *strictly* fundamental matters of handedness: the absolutist thinks they consist in the distribution of the physical property L that distinguishes the left from right hands, while the relationalist thinks they consist

[27] To be clear, it is not impossible to speak a language in which 'left' is defined as 'congruent to what members of my community call "left"'. My claim is just that a community using 'left' and 'right' as devices of coherence do not speak this language.

in relational matters of congruence. The relationalist I envisage then adds that matters of left and right are *loosely* fundamental, but that does not contradict her relationalism.[28]

We therefore have two senses in which something can be fundamental (unexplained). Insofar as a possible world is a way of reorganizing fundamental (unexplained) matters, we have two corresponding notions of a possible world. The *strictly possible worlds* discussed above, we now see, are ways of reorganizing *strictly fundamental* matters. For the relationalist, the strictly fundamental matters concerning handedness just concern relational matters of congruence; hence a strictly possible world just is a way of reorganizing relational matters of congruence (and other strictly fundamental matters concerning mass, etc.); hence strictly possible worlds agreeing on relational matters of congruence agree on all matters of handedness *per* Relational Supervenience. But for the absolutist, the strictly fundamental matters include the distribution of the physical property L that distinguishes left from right; hence a strictly possible world on his view is a way of reorganizing L (as well as other strictly fundamental matters); hence the absolutist can distinguish strictly possible worlds that differ only in a uniform flip of left to right and vice-versa *contra* Relational Supervenience. This is all as expected, for strict possibility is the normal sense of metaphysical possibility already familiar to philosophers.

By contrast, say that a *loosely possible world* is a way of reorganizing loosely fundamental matters. On the relationalist view under discussion, the loosely fundamental matters include relational matters of congruence *and* matters of left and right, so a loosely possible world is a way of reorganizing those relations *and, in addition, reorganizing what's left- and right-handed*. Even for a relationalist, then, matters of left and right can be freely stipulated of a loosely possible world; there is no need to require that they be fixed or settled by the relational facts at that world, so there is no danger of Incommensurability when it comes to loosely possible worlds. For the same reason, there can be loosely possible worlds that agree on all relational facts yet disagree only in a flip of left to right and vice-versa. Thus when it comes to *loosely* possible worlds, relationalism does *not* imply Relational Supervenience! Again, if this sounds odd just remember what loosely possible worlds are. Whereas strictly possible worlds represent how *factual* matters could have differed, loosely possible worlds represent how *all* matters could have differed—including non-factual matters. Thus for the relationalist, the loosely possible worlds that differ only in a flip of left to right agree in all *factual* respects; they disagree only in the non-factual respect of left and right.[29]

---

[28] In Dasgupta (2014a) I tried to get at this distinction between two senses of being "unexplained" in terms of plural grounding. Suppose a plurality of facts including X have an explanation when taken together, but X has no explanation on its own. Then there's one sense in which X has an explanation—it is explained as part of a plurality—and another sense in which it does not—it has no explanation on its own. But I've come to think that the framework of plural grounding doesn't helpfully illuminate the phenomena. That phenomena was the use of 'kilogram' predicates described in section 9 of that (2014a) paper, which in essence is the idea that such talk is a device of coherence like 'left' and 'right'. I still believe we use 'kilogram' talk that way (see section 10 of this paper) but I now think this usage is better understood in terms of non-factualism than plural grounding.

[29] This distinction between loose and strict possibility is closely related to Russell's (2015) distinction between possibility and factual possibility: in both cases the former represents how all matters, including non-factual matters, could have differed. However, he explicitly rejects the idea that there are two distinct notions of possibility in play; his aim instead is to understand Lewis' idea that distinct possibilities can "correspond" to the same possible world. I'm not exactly sure what this Lewisian idea amounts to and so am unsure to what extent our views really differ.

In this way the relationalist can recognize a distinct loosely possible world for each strictly possible world recognized by the absolutist. But is the converse also true? One might think not. After all, the absolutist (as we are imagining him) thinks that the *only* strictly fundamental matters of handedness are matters of left and right, and matters of congruence are settled by them. By contrast, the relationalist thinks that matters of left and right *and* matters of congruence are loosely fundamental. Does that mean there are weird loosely possible worlds that the absolutist makes no sense of, for example one in which there are two incongruent left handrons? In principle, yes. But more likely, the relationalist will think that the conditionals encoded in the exit rules (R1)-(R3)—for example, that if two handrons are both left-handed then they are congruent—are metaphysical principles. This is not *ad hoc*: on her view those exit rules are constitutive of meaning, and hence the encoded conditional is plausibly a conceptual or analytic truth. If that is right, then it follows that the relationalist does not in the end recognize these weird worlds that the absolutist cannot make sense of. Hence we have

> **Modal Correspondence Thesis:** There is a one-one correspondence between the space of *strictly* possible worlds recognized by the absolutist, and the space of *loosely* possible worlds recognized by the relationalist, that preserves all relational facts and facts about what is left and right.

And this is precisely what we were after!

9. How to Be a Relationalist

We can now see—finally!—how the relationalist can account for the use of 'left' and 'right' in scientific practice described in section 4. That practice included expressing observations of hadrons in those terms and writing down their theory of handrons as

(F) Whenever a handron collides with another, it changes color iff it is *left*-handed.

We saw in section 5 that if 'left' and 'right' are devices of coherence this practice makes perfect sense to a relationalist. The residual question was how to make sense of the deterministic reasoning in which (F) is used to solve initial value problems like Questions 2 and 3. That reasoning involved *characterizing* the possible worlds in terms of 'left' and 'right' and *distinguishing* worlds that are mirror images of one another, and the worry was the the relationalist can't make sense of that. The solution is now clear: the relationalist can interpret initial value problems as involving *loosely* possible worlds. After all, we know that the absolutist can interpret Question 2 as involving a *strictly possible world* containing two left-handrons, and Question 3 as involving a *distinct* strictly possible world containing two right-handrons. By the Modal Correspondence Thesis, the relationalist can do exactly the same with *loosely* possible worlds instead.

More generally, the relationalist can now say that (F) is deterministic. Recall from section 2 that we defined determinism in terms of possible worlds thus:

> A theory is *deterministic* iff any two possible worlds in which it obtains, and which agree at one time, agree at all times.

So we must now distinguish two notions of determinism, strict and loose, depending on whether "possible world" is understood in the strict or loose sense. We said in section 2 that (F), as the absolutist understands it, is deterministic, and in retrospect what we meant was that it is *strictly* deterministic—we were working with the standard sense of possibility, which we now call “strict possibility”. By the Modal Correspondence Thesis it follows that (F), as the *relationalist* understands it, is *loosely* deterministic. Or more cautiously, (F) is loosely deterministic on the relationalist’s interpretation if and only if it is strictly deterministic on the absolutist’s.[30]

But if the relationalist mimics the absolutist so closely, what then is her advantage? The answer is that she avoids the epistemic problem plaguing absolutism from section 3. Remember, the absolutist interprets (F) as stating that the handrons that change color are those with some physical property L, such as being aligned with some oriented field. But we never observed that handrons with *that* property change color. Everything would look exactly the same in a strictly possible world in which all handrons are flipped, so that the ones changing color are *anti*-aligned with the field. For the absolutist, the difference between these worlds is factual: there is a genuine fact about whether the handrons changing color are aligned with the field, a fact that can’t be known. But on the relationalist view there is no such fact. True, she can distinguish *loosely* possible worlds that differ only in a uniform flip of left to right, but the difference is merely non-factual. They differ in labels (as it were) but not in fact.

As emphasized in section 6, this approach is adequate only if loose possibility is a genuine species of metaphysical possibility. Otherwise I’ve not shown how the relationalist can say that (F) is deterministic *in the right sense*. The argument of sections 7 and 8 is that it is indeed a genuine kind of metaphysical possibility. The key lies in the connection between metaphysical possibility and constitutive explanation: that if something is constitutively unexplained—if there is nothing *making* it be that way—it could have been otherwise. What I then argued is that there are two related notions of being constitutively unexplained: strict and loose fundamentality. Each notion then gives rise to a corresponding notion of possibility: strict and loose possibility, respectively. Thus loose possibility is as much a genuine notion of metaphysical possibility as strict possibility is, and for the same reason.

This approach will be rejected by those seduced by the idea that there is a clear, univocal notion of “metaphysical possibility” that we grasp independently of its connection to fundamentality and explanation. On this view, metaphysical possibility may (as it happens) correspond to ways of reorganizing strictly fundamental matters, but no notion of metaphysical possibility corresponds to ways of reorganizing loosely fundamental matters. This view is antithetical to the approach I take here, on which there is no content to talk of metaphysical possibility apart from its connection to explanation. There is no space to settle this deep issue of modal metaphysics in this paper; I can only be explicit about what my approach is.

Still, even granting that loose possibility is an appropriately metaphysical modality, one may still object that it is not the right *kind* of metaphysical modality to use when defining notions like determinism. The worry would be that there is no reason why the relationalist should use *it*, rather than strict possibility, other than the *ad hoc* reason that things work out nicely for her if she does. But this objection gets things exactly back to front. After all, the difference between strictly and loosely possible worlds is that the former represent how the *factual* matters could

---

[30] The more cautious statement is more accurate because, of course, (F) itself isn’t really deterministic *at all*. One has a deterministic theory only by combining (F) with a determinist theory of motion; see footnote 10. But the point remains that on the absolutist’s view, any two strictly possible worlds that agree on (F) and agree on all facts of left and right at a time, agree on which handrons will collide upon collision. The point is that the same is true on the relationalist’s view vis a vis loosely possible worlds.

have differed, while the latter represent how *all* matters could have differed. Since the relationalist thinks that matters of left and right are non-factual, it follows that questions of how such matters could have differed are intelligible for her *only* as questions about loose possibility. It would therefore be perverse to expect her to model counterfactual reasoning about left and right with strictly possible worlds! To the contrary, loosely possible worlds are precisely what makes sense for her to use when thinking counterfactually about left and right, independent of the fact that things work out nicely for her if she does.

Even granting this, one might still worry whether loose determinism counts as *determinism* in any serious sense of the term. The worry is that in the definition of determinism it is important that worlds agree at a time if they agree in all respects *intrinsic* to that time. Otherwise, one could say that agreement at a time requires agreement in what *will* happen from that time onwards, in which case determinism becomes trivial. And the worry would be that matters of left and right are not intrinsic to a time, on the relationalist's view, since they serve to summarize relational matters of congruence that may hold between times. In response, I won't quibble over whether right and left count as intrinsic for the relationalist (I suppose we could distinguish loose and strict senses of 'intrinsic'…) The important point is that allowing agreement at a time to include agreement in matters of left and right does not render determinism trivial in the slightest. For the theory

(F*) When a left-hadron collides with another, there is an 80% chance that it changes color.

is not deterministic in either the loose or strict sense, so there is no danger that the notion of loose determinism is trivial.

Of course, for the relationalist 'left' and 'right' is just loose talk; it doesn't get at how things are at the (strictly) fundamental level. When doing physics in *strictly fundamental* terms, she will just talk in terms of congruence. Thus the strictly fundamental First Law of handrons will be:

(F-Minimalist) (i) If x and y are congruent handrons, then x changes color on collision iff y does too.
(ii) If x and y are incongruent handrons, then x changes color on collision iff y does not.

I argued in section 2 that this is indeterministic, and that is true in both the strict and loose senses. But as we saw in section 3 this is a *virtue* of relationalism since, fundamentally speaking, the indeterministic behavior described by (F-Minimalist) is all that we observe.

So here is the relationalist picture. At the strictly fundamental level, the world is an indeterministic system governed by (F-Minimalist). But we rarely represent matters of handedness in strictly fundamental terms; we typically use 'left' and 'right' as devices of coherence to characterize the world more efficiently. And characterized like *that*, handrons behave in the *loosely* deterministic manner expressed by (F). Thus, one the relationalist has introduced talk of 'left' and 'right' she'll reason about handrons in the same deterministic manner that the absolutist will; the only difference will be their interpretation of the reasoning.

Much the same goes for locality. We saw in section 2 that the absolutist's physics of handrons is local. For (F) says that whether a given handron will change color depends on whether it is left-handed, and for the absolutist this depends on whether it has that property L that distinguishes left- from right-handrons, not on its relation to far-off handrons. This was in contrast to (F-Minimalist), which says that whether a handron will change color depends on the results of other collision events that may occur thousands of miles away. But our mistake was to conclude that the relationalist's physics *in toto* is non-local. For her physics includes (F)—at least, it does unless she's restricting herself to strictly fundamental talk—and she can agree that (F) is local. After all, she agrees that whether a handron is left-handed doesn't depend on its relation to far-off handrons—on her view being left-handed is loosely fundamental and so doesn't depend on *anything*! True, the *correctness* of calling a handron 'left' may depend on congruence relations to far-off handrons, but *that it is left-handed* does not. In *that* sense she can agree that according to (F), whether a handron changes color does not depend on the results of far off collision events.

If one defines locality in terms of possible worlds, this point can be put in terms of strict and loose possibility just as it was with determinism. How might such a definition work? As Baker explains, the idea behind locality is that "approximately isolated systems can generally be treated as if they were entirely isolated" (manuscript, footnote 19). This is what allows us to model our solar system to a high degree of accuracy while ignoring the gravitational effects of Alpha Centauri. The idea is that if you ignore everything outside the system and pretend that it's its own possible world, this should have negligible effect on what the theory predicts about the system. Thus if S is an approximately isolated subsystem of a world W, locality amounts to the following idea: that the result of *first* taking a world that's an intrinsic duplicate of S at a time t0 *and then* evolving the duplicate forward to t1 according to the theory, is approximately the same as *first* evolving the entire world W from t0 to t1 according to the theory *and then* taking a world that's an intrinsic duplicate of S at t1. Thus, locality amounts to a kind of commutativity between the operation of taking a world that's an intrinsic duplicate of a subsystem at a time, and the operation of evolving a world over time according to the theory. Admittedly, precisifying this idea is somewhat complex and there is room to quibble over the details. But those details don't matter to the general point. Take *whatever* possible worlds definition of locality you like; we can then distinguish strict vs loose locality depending on whether the worlds are read as strict or loosely possible worlds. By the Modal Correspondence Thesis, (F) is loosely local on the relationalist's interpretation if and only if it is strictly local on the absolutist's.[31]

And the same goes for other modal reasoning about left and right concerning counterfactuals, causation, explanation, and so on: the relationalist will exactly mimic the absolutist's reasoning, differing only in her interpretation of what it means. Thus, suppose an absolutist asserts a counterfactual such as 'Had two left-handrons collided, they would have changed color". And suppose he interprets this as having a possible-worlds truth-condition a la Lewis-Stalnaker. Then the relationalist can agree, adding just that she interprets the truth-condition as involving loose rather than strict possible worlds.

---

[31] Here is one way to precisify a possible worlds definition of locality. Given a theory T and a subsystem S of a world W, call the worlds in which T is true and whose complete state at t duplicates the intrinsic state of S at t the *isolated* $S_{T,t}$ *worlds*. These worlds represent how S can evolve from t, according to T, if we ignore the rest of the world W. Then take the worlds that agree with W at t and in which T is true, and call the subsystem S in each world an *embedded* $S_{T,t}$ *system*. These represent how S can evolve from t, according to T, if we take into account the rest of the world W. Finally, say that the embedded $S_{T,t}$ systems *match* the isolated $S_{T,t}$ worlds iff there's a 1-1 correspondence between them that maps each system to a world that's an approximate intrinsic duplicate. Then we can define a theory T to be *local* iff for any world W, any approximately isolated sub-system S of W, and any time t, the embedded $S_{T,t}$ systems match the isolated $S_{T,t}$ worlds. This can then be interpreted over strictly or loosely possible worlds as indicated in the text.

This might sound odd. If a hadron's being left-handed is non-factual, how could there be scientifically respectable counterfactuals regarding how left-handrons would behave? How could being left-handed play a role in scientific explanation or causation? The worry would be that only factual matters can be "real" pushes and pulls. But remember, the relationalist is not trying to say that being left-handed does any work *at the strictly fundamental level*. She is rather earning the right to speak like an absolutist, with no pretense that this is getting at how things are most fundamentally in the strict sense. Thus, she will happily say that a handron changes color because it is left-handed, so long as it is noted that this is not getting at the strictly fundamental pushes-and-pulls.

10. Mass

That is how to be a relationalist about handedness. Let me now explain how the approach carries over to the case of mass and discuss Baker's arguments I mentioned at the beginning.

As with handedness, the issue of absolutism vs relationalism concerns the *strictly fundamental* facts about mass. The relationalist thinks they just concern how bodies are related in mass, for example that *x* is less massive than *y*, or twice as massive as *z*. Relationalists may disagree on which relations are strictly fundamental—orderings, ratios, or something else—but for our purposes nothing hangs on this and I'll assume they're ratios for simplicity. By contrast, the absolutist thinks that the strictly fundamental facts concern which intrinsic mass each body has, and these then settle their mass relationships: if *x* is more massive than *y* this is because of their respective intrinsic masses.

In the case of handedness a central question was the interpretation of 'left' and 'right'. Here the corresponding question is the interpretation of units such as 'kilogram'. For the absolutist, a natural interpretation is that terms like '1 kg' and '2 kg' directly refer to intrinsic masses. She might add that their referent is fixed by a description involving a standard object—perhaps '1 kg' is to refer to that intrinsic mass possessed by the standard kilogram in Paris. But however reference is fixed, the view is that kilogram terms make direct reference to strictly fundamental properties.[32]

How might the relationalist interpret kilogram talk? One option is to define '1 kilogram' to be synonymous with 'equal in mass to the standard kilogram in Paris'—this is like defining 'left' as 'congruent with Changy'. But the better option is to understand 'kilogram' as a device of coherence, just as we did with 'left' and 'right'. On this view, predicates of the form '*x* is *r* kilograms' are stipulated to be governed by the following exit-rule:

> (K)
> x is r kilograms
> y is s kilograms
> Therefore, x is r/s times as massive as y

But one stipulates nothing else: there are no intro-rules that specify sufficient conditions for concluding (say) that a given body is 2 kgs, so the predicates have no explicit definition. Nonetheless, this is sufficient to ground a meaningful practice in which the predicates are used

[32] While the term '1 kg' contains a numeral, on this view it makes direct reference to a particular intrinsic mass and not the number. Thus this is not the "pythagorean" via on which numbers are fundamentally enmeshed in matter.

to record information about mass-ratio. When first applying the predicates to a body one has free reign—one can call it 1 kilogram, 2 kilograms, whatever. But if one calls it 2 kilograms then subsequent usage is constrained: given another body twice as massive as the first one must call it 4 kilograms else one could infer a falsehood via (K). Thus one's aim in applying these predicates of mass-in-kilograms is to *cohere* with one's neighbors in the sense that the combined uses imply truths about mass-ratio via the rule (K). On this view, the standard object in Paris plays no semantic role in defining or fixing the referents of kilogram terms. Its role is rather to help billions of language users worldwide cohere: we can all aim to cohere with the statement 'The standard kilogram is 1 kilogram'.

I believe that this is, in all important respects, how *our* talk of mass in kilograms actually functions.[33] But that is an empirical hypothesis that I will not defend here. All I need is the uncontroversial claim that it's *possible* for a community of relationalists to use 'kilogram' like this. If they do, their kilogram talk will be non-factual for the same reason as with 'left' and 'right'. For in uttering 'x is 2 kilograms' their aim is not to describe but to cohere; hence the utterance is correct not because it is true but because it coheres. Thus, matters of mass in kgs are *loosely* fundamental, again for the same reason: there's no constitutive explanation of why x is 2 kilograms, just an explanation of why 'x is 2 kilograms' is correct.

When it comes to counterfactual reasoning, then, the relationalist will distinguish strict from loose possibility just as before. The strictly fundamental matters about mass just concern mass-relationships; and so a strictly possible world is just a reorganization of mass-relationships (along with other strictly fundamental matters unrelated to mass); hence *strictly* possible worlds agreeing on all mass-relational matters must agree on all matters of mass. This is the analogue of Relational Supervenience in the case of mass. But the *loosely* fundamental matters include matters of mass in kgs; hence a loosely possible world includes a reorganization of the mass in kgs of each thing; hence there can be loosely possible worlds that agree on all relations of mass and disagree only in a uniform doubling of mass in kgs. Indeed, this space of *loosely* possible worlds will correspond one-one with the space of *strictly* possible worlds recognized by the absolutist, for the same reasons as before. Thus we have:

> **Modal Correspondence Thesis for Mass:** There is a one-one correspondence between the space of *strictly* possible worlds recognized by the absolutist, and the space of *loosely* possible worlds recognized by the relationalist, that preserves all mass relational matters and matters of mass in kgs.

We can now see how a relationalist can interpret a physics of mass. Imagine some fictional physicists who observe the behavior of massive bodies and record their measurements in units like mass in kgs and acceleration in m/s^2. And imagine their observations confirm a classical theory consisting of f=ma and various force laws, where f=ma is to be understood as

(N) The total force in Newtons acting on a body = its mass in kgs times its acceleration in m/s^2.

and the equations describing force laws are understood similarly. Imagine further that they use this theory to solve initial value problems like Baker's cases involving escape velocity. One problem involves a planet with a rocket on its surface, each with a specified mass in kilograms,

[33] See Dasgupta (2013, section 4) and (2014, section 9) for arguments to this effect.

and the rocket is fired upwards at a specified velocity. The question is whether the rocket will escape the planet's gravitational field, and the answer is that it does. A second problem is just like the first except the planet and rocket are double in mass what they were in the first, and in this case the rocket does not escape. Note that the initial states are *characterized* in terms of kilograms and they're *distinguished* only by a uniform doubling thereof. These are therefore analogous of Questions 2 and 3 concerning handedness, which were characterized in terms of left and right and distinguished only by a uniform flip (indeed I designed Questions 2 and 3 to be analogous to Baker's cases). Baker shows that the theory behaves *deterministically* insofar as it entails a unique solution for each problem. Indeed, let's imagine that the theory satisfies the standard possible worlds definition of determinism from section 2.[34]

To the absolutist this all makes perfect sense. Measurements of mass in kgs are measurements of a strictly fundamental quantity, namely intrinsic mass, and equations like (N) describe how this quantity relates to others. Initial value problems characterize the initial state of a *strictly* possible world with respect to this quantity, and since on his view strictly possible worlds can differ in a uniform doubling of mass there is no problem distinguishing the two problems. And the theory is strictly deterministic insofar as any two *strictly* possible worlds in which it holds, and which agree at one time, agree at all other other times—that's why the theory yields a unique solution in each case.

The relationalist can make good sense of this too, but her interpretation is different. On her view measurements of mass in kgs aren't descriptions of a strictly fundamental quantity, they're statements in a derivative and non-factual vocabulary designed to conveniently store information about the underlying mass relationships. Thus an equation like (N) isn't a *strictly fundamental* physics of mass, it's what physics looks like when presented in this derivative and non-factual vocabulary of mass in kgs. Since talk of kgs is non-factual, reasoning about how things could have differed in kgs must involve loose, not strict, possibility—after all, strictly possible worlds don't represent how non-factual matters could have differed. Thus the relationalist will naturally take Baker's initial value problems to characterize the initial state of two *loosely* possible worlds. By the Modal Correspondence Thesis for Mass, the relationalist can distinguish two such problems differing only in a uniform doubling of mass just as the absolutist can! Indeed, the correspondence shows that the relationalist's theory must be loosely deterministic if and only if the absolutist's theory is strictly deterministic.

Why then did Baker think that relationalism about mass leads to indeterminism? He noted that the initial states of the two problems agree on all mass relationships (and in all respects other than mass); hence on the relationalist's view their initial states agree in *all* respects simpliciter. Since they diverge thereafter, this is indeterminism. Moreover, he argued ingeniously that the relationalist must agree that there are indeed *two* ways for that initial state to evolve.[35] But the mistake was to think that since they agree on all mass relationships they must agree in *all* respects of mass. That would be right, on the relationalist's view, *if* they are strictly possible

[34] To be clear, classical mechanics is arguably not deterministic; see Norton (2008). But these kinds of failures of determinism are not germane to our discussion so I'll bracket them here.

[35] The argument is this. Consider a third initial value problem containing *two* planet-rocket systems with one system double the mass of the other, and let the systems be sufficiently far apart that they're more or less isolated. And suppose the rocket in the less massive system escapes while the other rocket does not. The relationalist must agree that this is possible. But by locality, the behavior of each system doesn't depend on its relation to the other, so each would behave similarly were it it's own possible world. Thus we have two worlds that agree initially on all mass relationships (and all respects other than mass) yet diverge thereafter.

worlds. But on her view they're not: they're loosely possible worlds, and as we know she can distinguish two such worlds that differ only in a uniform doubling of mass in kgs. Thus, there's no failure of determinism: there are indeed two ways for the initial state *characterized relationally* to evolve, but each way corresponds to a different initial state vis a vis mass in kgs.

Nonetheless, Baker is right that indeterminism lurks in the vicinity. For what would the relationalist's physics look like if expressed in *strictly fundamental* terms? She would restrict herself to talk of mass relationships and so couldn't propose (N). In its place, one option would be a Machian alternative that contains reference to a particular body, such as:

(N-Machian) The total force in Newtons acting on a body = its mass ratio with the standard kilogram in Paris times its acceleration in m/s^2.

But this inherits the same problems with Machian laws discussed in section 2: it doesn't apply to worlds in which the standard object in Paris doesn't exist. Better is a minimalist theory that stands to (N) just as (F-Minimalist) stands to (F). Such a theory is complex to write down in full generality, but the idea is that it would imply statements like

(N-Minimalist) If one body is *r* times as massive as another and they are both subject to the same force, the first will accelerate at 1/*r* the rate as the second.[36]

And (N-Minimalist) is indeterministic and non-local in both the strict and loose sense, just like (F-Minimalist) was. After all, it implies *nothing* about how a world containing just one body will evolve over time (indeterminism), and it implies that a body's rate of acceleration depends on how other bodies many thousands of miles away are accelerating (non-locality).

But as with handedness this is a virtue: the indeterministic and non-local behavior described by (N-minimalism) is all we really observe! In particular, we did not observe the deterministic behavior described by the absolutist's interpretation of (N). Recall that on that interpretation (N) states how a body with a particular intrinsic mass M would accelerate under a given force. But we never observed that *that particular mass M* affects acceleration in that way, since everything would look (and smell, and taste) exactly the same in a uniformly mass-doubled world. In that world, the mass that's *half M* would affect acceleration in the same way that M actually does, and the behavior of all the other intrinsic masses would be similarly transformed.[37] What we actually see gives no reason to think we live in the one world over its doubled cousin. All we really observe are the relational facts common to both worlds, namely that bodies accelerate at a rate inversely proportional to their mass. But that just confirms (N-Minimalist), not the absolutist's interpretation of (N).

The upshot is this. When it comes to *strictly fundamental* physics, the relationalist proposes (N-Minimalist) while the absolutist proposes (N) interpreted as stating how particular intrinsic masses affect acceleration. The absolutist's theory goes beyond what's confirmed by observation, the relationalist's does not; that's a point in favor of relationalism. True, the

---

[36] See Field (1980) for a proper articulation of what a set of minimalist laws like this might look like.

[37] In the doubled world, would (N) be true? Yes and no. What (N) actually states, in our mouths, is false at that world: the intrinsic masses line up with rates of acceleration differently than (N) states. But our counterparts in the doubled-world, using the terms as we do, would express a truth with (N). For their term '1 kg' would pick out a different intrinsic mass than ours and therefore what (N) means in their mouth would be true.

relationalist's theory is indeterministic and non-local, but that's a virtue since that's all that observation confirms. Still, when reasoning about mass the relationalist will find great utility in using kilograms as a device of coherence, and when she does physics in these terms she'll propose (N) and reason counterfactually in terms of loose possibility. Her physics will then behave on the surface just like the absolutist's: it is deterministic and local (in the loose senses), and initial value problems are solved in just the same way as the absolutist thought. The only difference lies in the interpretation of this practice. For the absolutist it gets at how things are at the strictly fundamental level, while for the relationalist it is, ultimately, just convenient short-hand.

11. Conclusion

In both handedness and mass, then, the success of relationalism hangs centrally on the interpretation of the vocabulary of 'left' and 'right', and 'kilograms', respectively. This issue has received insufficient attention. Sometimes it's presumed that the relationalist has no right to such vocabulary—witness Earman saying that the relationalist cannot so much as *express* the law (F) since it contains the term 'left'. Other times the relationalist is allowed the vocabulary but it's presumed to behave modally much like other vocabulary—witness Baker's assumption that if two initial value problems agree in all mass-relational respects then the relationalist must count them as agreeing in all respects of mass. But both presumptions are wrong. The relationalist can interpret the contested talk as a device of coherence, and if she does its modal behavior will mimic how the absolutist always thought it behaved.

Indeed, this explains why absolutism initially strikes many as the more plausible view. For being left or right-handed, and having a particular mass in kgs, certainly *appear* to be independent variables, states that hold independently of relations of congruence and mass ratio respectively. Relationalism has always been *thought* to deny this appearance; hence the plausibility of absolutism. But we now know that a relationalist needn't deny the appearance. They *are* independent variables, she can say, insofar as something's being left-handed and being 2 kgs doesn't hold in virtue of anything! But the idea that a relationalist (of all people) can say this is only apparent once we reflect on her interpretation of the relevant vocabulary and recognize it as a device of coherence.

I've applied this approach to the cases of handedness and mass; could it also apply to other domains in which there is an analogous dispute between absolutist and relationalist views? These include the case of motion discussed at the beginning, and also disputes about the interpretation of 'gauge' theories. The question is whether the language used by the absolutist to describe his extra feature of reality can be interpreted by the relationalist as a device of coherence. If so, the relationalist can largely mimic the absolutist in the ways I've indicated above. But I leave a discussion of these other cases for another time.[38]

[38] This paper has been in the making far too long and I've received feedback from more people than I remember. Daniel Berntson, Neil Dewar, Niels Martens, Michaela McSweeney, John Morrison, Jack Spencer, and Nat Tabris all suffered through early versions of the manuscript and responded with undue politeness; I thank them for their probing questions. I also thank audiences at Rochester University, Columbia University, Princeton University, Brown University, and the National Autonomous University of Mexico, for engaging with this material at various stages of its development. But most of all, I thank David Baker for raising these issues of determinism and locality and for discussing this material with me over the years. These conversations with Baker have invariably been a model of good philosophical interaction.

References

Baker, David (manuscript). "Some Consequences of Physics for the Comparative Metaphysics of Quantity".

Boghal, Harjit (forthcoming). "Nomothetic Explanation and Humeanism about Laws of Nature". *Oxford Studies in Metaphysics*.

Brighouse, Carolyn (1994). "Spacetime and Holes". *PSA: The Proceedings of the Biennial Meeting of the Philosophy of Science Association* 1: 117-25.

Brighouse, Carolyn (1999). "Incongruent Counterparts and Modal Relationalism". *International Studies in the Philosophy of Science* 13(1): 53-68.

Dasgupta, Shamik (2013). "Absolutism vs Comparativism About Quantity". *Oxford Studies in Metaphysics: Volume 8*: 105-148.

Dasgupta, Shamik (2014a). "On the Plurality of Grounds". *Philosophers' Imprint* 14(14): 1-28.

Dasgupta, Shamik (2014b). "The Possibility of Physicalism". *The Journal of Philosophy* 111(9): 557-592.

Dasgupta, Shamik (2015). "Substantivalism vs Relationalism About Space in Classical Physics". *Philosophy Compass* 10(9): 601-624.

Dasgupta, Shamik (2016). "Metaphysical Rationalism". *Nous* 50(2): 379-418.

Earman, John (1989). *World Enough and Space-Time: Absolute versus Relational Theories of Space and Time*. Cambridge, MA: MIT Press.

Field, Hartry (1980). *Science Without Numbers*. Oxford: OUP.

Field, Hartry (2001). "Deflationist Views of Meaning and Content". In *Truth and the Absence of Fact*. Oxford: OUP.

Gibbard, Alan (2003). *Thinking How to Live*. Cambridge: Harvard University Press.

Kovacs, David (manuscript). "Metaphysically Explanatory Unification".

Lee, Geoffrey and Seth Yalcin (manuscript). "Finding Meaning in a Disoriented World".

Maudlin, Tim (2014). *Philosophy of Physics: Space and Time*. Princeton: Princeton University Press.

Norton, John D. (2008). "The Dome: An Unexpectedly Simple Failure of Determinism" *Philosophy of Science* 75(5): 786-798.

Pooley, Oliver (2003). "Handedness, Parity Violation, and the Reality of Space". In *Symmetries in Physics: Philosophical Reflections*, edited by K. Brading and E. Castellani, pp. 250-280.

Rosen, Gideon (2010). “Metaphysical Dependence: Grounding and Reduction”. In *Modality: Metaphysics, Logic, and Epistemology*, edited by B. Hale and A. Hoffman, pp. 109-36.

Russell, Jeff (2015). “Possible Worlds and the Objective World”. *Philosophy and Phenomenological Research* 90(2): 389-422.

Saunders, Simon (manuscript). “Incongruent Counterparts: A Leibnizian Approach”.

Schaffer, Jonathan (2016). “Grounding in the Image of Causation”. *Philosophical Studies* 173(1): 49-100.

Schaffer, Jonathan (forthcoming). “The Ground Between the Gaps”. *Philosophers' Imprint*.

Sider, Ted (2011). *Writing the Book of the World*. Oxford: OUP.

Sklar, Larry (1974). *Space, Time, and Spacetime*. Berkeley: University of California Press.

Wilsch, Tobias (2015). ‘The Nomological Account of Ground”. *Philosophical Studies* 172(12): 3293-3312.

Wilson, Jessica (2016). “Grounding-Based Formulations of Physicalism”. *Topoi.*

Yalcin, Seth (2012). “Bayesian Expressivism”. *Proceedings of the Aristotelian Society* 62: 124-160.