ABSTRACT

A Relational View of Time

Daniel Padgett, Ph.D.

Advisor: Alexander R. Pruss, Ph.D.

This dissertation is a defense of an Aristotelian, relational view of time. The Aristotelian holds that there are both fundamental and derivative entities. The relationalist maintains that time is not one of the fundamental entities but instead depends on, and is derived from, fundamental entities that change. In chapter one I discuss what, exactly, a view of time must take a stance on in order to be complete. This discussion results in a taxonomy for different views of time. With this taxonomy in mind, I give a selective survey to the history of the philosophy of time, paying particular attention to the views of Aristotle and Leibniz, of which my view is a successor. In chapter two I lay the groundwork of an Aristotelian ontology. In particular, I discuss how certain kinds of entities are grounded by fundamental entities. This plays a key role in motivating the claim that times are derivative entities. Chapter three is an exposition of common challenges and objections to relationalism. In this chapter we see how contemporary views of physics have factored into the debates in the philosophy of time. The answer to these challenges and objections comes in chapter four, in which I offer my view of time. While my view is a descendant of those of Aristotle and Leibniz, I make use of A.N. Prior's work on world states to state my view. After presenting my view, I answer the challenges and objections from chapter three and place my view within

the taxonomy presented in chapter one. The final two chapters address views that are competitors to mine, considering first kindred versions of relationalism, and then arguing against substantialism, the view that time (or spacetime) is a fundamental entity. Substantivalism is the main rival to relationalism, and it comes in several forms. After arguing that not all versions of substantivalism are equal, I make my case against the most plausible form of substantivalism, which says that the only fundamental entity is spacetime.

A Relational View of Time

by

Daniel Padgett, B.A., M.A.

A Dissertation

Approved by the Department of Philosophy

Michael D. Beaty, Ph.D., Chairperson

Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of
Doctor of Philosophy

Approved by the Dissertation Committee

Alexander R. Pruss, Ph.D., Chairperson

J. Todd Buras, Ph.D.

Trent Dougherty, Ph.D.

Jon Harrison, Ph.D.

Jonathan L. Kvanvig, Ph.D.

Accepted by the Graduate School
August 2016

J. Larry Lyon, Ph.D., Dean

Page bearing signatures is kept on file in the Graduate School.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

First and foremost I want to thank Alexander Pruss. This dissertation has been greatly improved by his helpful comments, encouragements, and insightful objections. I cannot thank him enough for being a fantastic advisor and mentor.

I have also benefitted from the rest of my committee. Todd Buras, Trent Dougherty, Jon Harrison, and Jon Kvanvig have all played an important role in my graduate studies at Baylor, whether through conversation or mentoring (even if they were not aware that that's what they were doing!).

I would also like to thank Ryan Byerly, Hud Hudson, Meghan Page, Amy Seymour, Bradley Rettler, Patrick Todd, and Chris Tweedt for helpful discussion and questions about various parts of this thesis.

And finally, I am grateful for the support of my family and community of friends. Without their support I could not have completed this project.

CHAPTER ONE

Introduction

This dissertation is a defense of an Aristotelian, relational view of time. The Aristotelian holds that there are both fundamental and derivative entities. The relationalist maintains that time is not one of the fundamental entities but instead depends on, and is derived from, fundamental entities that change. Relationalism has fallen out of favor because of the general theory of relativity (GR). GR has prompted allegiance to substantivalism, the view that time (or spacetime) is a fundamental entity. Due to a resurgence of Aristotelian metaphysics and a looming shift in our best physical theories, now is a good time to examine whether one should be a substantivalist. In this dissertation, I argue that one should not. Given an Aristotelian ontology, relationalism is the better view. Given that substantivalism is the current orthodoxy, another way of stating the main conclusion of this dissertation is that the current orthodoxy about the ontology of time (and spacetime) is mistaken.

Of course, one's view of the ontology of time is not limited to substantivalism or relationalism. One could instead be an anti-realist about time and maintain that time does not exist. I've chosen to ignore this option, though the groundwork for an argument against anti-realism is laid in this dissertation. Since the Aristotelian maintains that there are non-fundamental entities, the claim that no entity, whether fundamental or derivative, is time, becomes harder to justify than on an ontology with only one level of being.

The debate over whether time is a fundamental entity is not the only (and, as of late, not the primary) debate in the philosophy of time. The philosophy of time literature tends to focus on two related debates. The first is the quarrel between presentists and eternalists. Presentists and eternalists argue over what exists: the presentist maintains that it is only the present (i.e. presently existing objects) that exist, whereas the eternalist claims that the past, present, and future all exist. The second is a dispute over the nature of the present. The main parties in this dispute are A-theorists and B-theorists. The former claim that the present is metaphysically privileged—even if, as some A-theorists maintain, the past, present, and future all exist. The latter deny that there is anything metaphysically special about the present: the past, present, and future all exist, but that division is, for instance, just a byproduct of how we experience the world.

In chapter two I discuss what, exactly, a view of time must take a stance on in order to be complete. This discussion results in a taxonomy for different views of time. One upshot of this chapter is that the debates mentioned in the previous paragraph are not central when it comes to articulating a complete view of time. I argue that one can have a complete view of time without taking a stance on presentism and eternalism. And insofar as part of the A-theory/B-theory debate requires a stance on eternalism, deciding whether you are an A-theorist or a B-theorist does not play a crucial role in arriving at a view of time. That said, the origin of the A-theory/B-theory debate, which is focused on the question of whether tense is an ineliminable aspect of reality, is a question that one must answer in order to articulate a complete view of time. There are two other questions that one must answer in order to have a complete view of time. First: Is time a fundamental entity, a derivative entity, or not an entity at all? Second: Can the direction of time be reduced to—i.e. does time "go" this way rather than another way because of—something (such as entropy)? These three theses yield a taxonomy for possible views of time.

Chapter two also includes a selective survey of the history of the philosophy of time, paying particular attention to the views of Aristotle and Leibniz, of which my view is a successor. This survey is given, in part, to show that the taxonomy of views of time is a good one: that views of time fall under one of the classifications delineated by the taxonomy.

In chapter three I lay the groundwork of an Aristotelian ontology. In brief, an Aristotelian ontology is hierarchical: there are different levels of being, ordered by a grounding relation, where the more fundamental entities ground the less fundamental entities. A hierarchical ontology has a number of advantages over a flat ontology, i.e. an ontology on which there is only one level of being. For instance, I offer semantics for one kind of grounding relation, abstraction. Abstraction allows us to talk about kinds without being committed to Platonic entities. Kinds exist, but they are not fundamental. I also gesture at how one could construct non-fundamental entities. While my proposal for construction is far from complete, it is suggestive; and if something like the view of construction I offer is right, then it looks as if grounding pluralism is tied to ontological pluralism. Contrary to a well-received view, we would then say that the grounding relation is univocal iff there is exactly one fundamental entity.

The Aristotelian's commitment to non-fundamental entities lends itself to a discussion of substantivity. Within an Aristotelian framework, we can state the conditions under which a debate is nonsubstantive, or merely verbal. An import consequence of this discussion is that, when we are dealing with non-fundamental entities, a functionalist attitude is often the best attitude to adopt. For instance, if numbers are not fundamental entities, then which non-fundamental entity is the number 2 should be determined by considering what roles the number 2 plays, and then seeing which non-fundamental entities are suited to play those roles. This is an important result for the relationalist, for it means that the relationalist will not, as a rule, be concerned with finding the derivative entity that is time. Instead, the relationalist will be concerned first with finding out what roles time plays and second with finding (by abstraction or construction) an entity that is suited to play those roles. This is an important point to bear in mind for chapter six, which is where I considered alternate candidates for times. I conclude chapter three by discussing the change from talking about space and time to talking about spacetime. I argue that this change is a substantive change iff substantivalism is true. In other words, it is only the substantivalist who needs to consider whether time is fundamental or whether spacetime is.

Chapter four is an exposition of common challenges and objections to relationalism, as well as a discussion of the data that need to be accounted for. While not disjoint, I group these challenges, objections, and data under three categories: the problem of change, the folk theory, and physics. The discussion within each category is a convenient way to focus our attention so that the resulting view of time address all three theses mentioned in chapter two. Of the challenges, objections, and data considered, those that are attributed to physics are often thought to pose the greatest threat to relationalism. Specifically, the relationalist seems to face problems with expressive power and theoretical unity—especially when we take General Relativity as our physical theory. The objections from expressive power contend that there will be claims about distance that the relationalist cannot account for unless she (a) adopts a field ontology or (b) posits an infinite stock of primitive predicates. But if the relationalist opts for (a), her view no longer looks all that distinct from substantivalism; in fact, one could argue (as Tim Maudlin does) that relationalism becomes a merely verbal variant of substantivalism. On the other hand, option (b) is objectionable because we will be unable to state how the infinite stock of predicates are related. This is a problem because it seems obvious how "x took two minutes to complete" is related to "x took four minutes to complete": the latter takes twice as long as the former. So, even though the infinite stock of predicates solves the problem of expressive power, it does so at the cost of theoretical unity.

The answers to these challenges and objections come in chapter five, in which I offer my view of time. The core commitment of relationalism is that time ontologically depends on change. So, were there a world in which nothing changed, there would be no time. (There might be a single instant, but that would be it.) Given this, my view "takes tense seriously" in that statements that do not refer to a time are a more accurate reflection of the fundamental than are statements that do refer to a time. (Alternatively, statements that only refer to substances to report the changes substances undergo are a more accurate reflection of reality than statements that require a time to report how substances change.) This commitment leads me to build a theory of time around tense logic. While tense logic has been shown to be an inadequate theory of verb tense, it does have promise as a theory of temporal structure. To have a view of time, we need more than just temporal structure: we need times as well. While functionalism is at the heart of my view, I put forth a view of times that is based on A.N. Prior's work on world states. World states are sentences that tell us everything that is going on in the world when they are true. A world-state system is a maximal collection of world states. So, my view of time is that time is a world-state system, where the world states are ordered by the appropriate collection of tense logic axioms.

Given this view of time, we are able to define a metric on (at least some) world-state systems, which allows us to underwrite claims about how long some process take. The interesting feature of this account is that the relation chosen to be a metric is determined in part by the laws of nature or fundamentality, and in part by convention. The laws of nature or fundamentality determine a range of candidates that are qualified to play the role of the temporal metric, and then it is up to us to choose one based on convenience. For instance, both *Earth rotates x number of times around the Sun* and *Mars rotates x number of times around the*

Sun are qualified to play the temporal metric role, but the former is clearly a more convenient candidate for us.

With my view on the table, I show that my view is complete and is able to account for the data, objections, and challenges posed in chapter four. Accounting for the folk theory and the problem of change is easier than answering the physics-based challenges to relationalism. To meet the physics-based objections, I first show how one can define a number of relations on events using world states. I then show that world-state systems can be used as surrogates for classes of reference frames. This, combined with the relations on events, is enough to account for the relativity of simultaneity. I then show how the relationalist can respond to both the problem of expressive power and the worry about theoretical unity. The response here is two-fold. One part of the response shows that, given an Aristotelian framework, one can be a scientific realist without holding that every entity in our best scientific models is a fundamental entity. So, even if our best models contain fields, that does not force the relationalist to accept fields as fundamental entities. Thus, the worry that relationalism ends up being a merely verbal variant of substantivalism is unfounded. The second part of the response shows that the relationalist has three different ways to underwrite claims about temporal distance, each of which makes it clear that the various temporal relations are related to one another. Thus, the problem of expressive power loses its teeth.

In chapters six and seven I address views that are competitors to mine, considering first kindred versions of relationalism, and then arguing against substantialism. Since functionalism is at home on a relationalist view, chapter six does not aim to say that world states are the only candidate for times. Instead, the goal is to show that, of several other plausible candidates, there is reason to favor the view that times are world states (or at least a view that is highly similar to that one). That said, I do argue that times cannot be pure temporal locations. If times are pure temporal locations, then we need some other kind of entity to tell us what happens at each location. I survey several plausible candidates and conclude that each has considerable problems or unpalatable consequences. I close the chapter by considering an argument, given by Ryan Byerly and me, that most views of time are not "modally flexible", which is a significant mark against the view. For instance, it is true that, while I did not go running yesterday, I could have. But views of times on which times are identical to some abstractum cannot account for this truth and thus are not modally flexible. I then discuss ways that one can respond to this objection and offer a way to modify our semantics for counterfactual claims about the past (or future) and show how the view that times are world states is modally flexible.

Chapter seven of this dissertation makes a case against substantivalism. Substantivalism is the main rival to relationalism, and it comes in several forms. My argument against substantivalism has two stages. In the first stage I show that not all versions of substantivalism are equal. In fact, there is a best version of substantivalism, which I call Spacetime Wholism. Spacetime Wholism is the view that there is exactly one substance and it is spacetime. All other versions of substantivalism are not as plausible as Spacetime Wholism, and the extent to which such a contrastive claims is evidence that the inferior views are false, we have reason to suspect that all versions of substantivalism other than Spacetime Wholism are false. The second stage is a direct argument against Spacetime Wholism as well as the next best version of substantivalism, Container Substantivalism, on which spacetime is an independent entity in which material objects are contained. These arguments are based around the Hole Argument, which considers what happens when we redistribute metric fields inside of some arbitrarily small region of spacetime. In brief, the Hole Argument contends that a redistribution of the metric fields within an arbitrarily small region does not represent a distinct physical situation—but the substantivalist must maintain that it does. The Hole Argument was originally formulated against

Container Substantivalism, but I modify the argument to show how it can be used to make a convincing case against Spacetime Wholism as well.

CHAPTER TWO

Setting The Stage

In this chapter I offer a taxonomy of views of time that exhausts logical space. The partition of logical space that I offer subsumes the positions one can take in both the A-theory/B-theory debate and the substantivalism/relationalism debate. The taxonomy that I propose is necessary because neither of the aforementioned debates adequately carves up logical space on their own; that is, taking a position in neither debate gives one a worked out theory of time. To show this, I'm first going to offer the taxonomy and then consider several views in the history of the philosophy of time. The majority of the views I consider are in step with the view that I defend. While I restrict myself to only a small number of views, it will be clear that my taxonomy subsumes the main ways in which debates in the philosophy of time have been characterized.

2.1 What There Is

Kit Fine (2005, Ch. 8) notes that any theory may fail to capture reality in at least one of three ways.[1] First, the theory may be ontologically unfaithful: the theory may not faithfully represent *what* there is. Second, the theory may be ideologically deficient: it may not faithfully represent *how* things are. Third, the theory might have a factive deficiency: it may "depict *that* things are so, when it is not even in the business of stating how things really are" (Fine 2005, 267). For instance, the billiard ball model of a gas is factively deficient: the model uses billiard balls to say something about how a gas behaves, but it is obvious that the model is not

[1] Two comments. First, Fine says this about representations; but a theory is a kind of representation, so the same moral should apply. Second, "reality" is a technical term for Fine; I'm using it in a more general sense. Specifically, I say that anything that exists is real, whereas Fine says that only the fundamental is real.

intended to say something about what a gas is made up of since a gas is clearly not a collection of billiard balls. Of these three ways of evaluating a theory, the first two serve as a good way to think about how to carve up logical space with respect to some subject: we first ask *what* there is, and then ask *how* it is.

To answer the question of what there is, we need a way of talking about what there is. As we'll see in the next chapter, existence is cheap. There are many things that exist: feelings and unicorns, as well as you and I, are among them. Some things have more ontological weight than others, but that is a discussion I do not take up until the next chapter. For now I only want to flag that "exists", "thing", and "entity" are convenient words to talk about what exists and are used permissively throughout this chapter.

The question of what there is has a quantitative component to it: one could answer the question by saying "nothing", "one thing", or "multiple things". The last answer immediately raises a question about the relationship between the multiple things: could each exist independently of the others, or are some of the things ontologically dependent on some of the other things? To give these two kinds of entities a name, let's call things of the former kind *independent* and things of the latter kind *dependent*. So, a dependent thing depends for its existence on other things, and an independent thing does not depend for its existence on other things. Thus, when we ask whether something exists, we can reply that it doesn't, or that it does and is independent of other things, or that it does and is dependent on other things.[2] With respect to what there is, non-existence, independent existence, and dependent existence exhaust one's ontological options.

2.2 What Time Is Like

Answering the question of whether time exists does not give a full theory of time. It is not enough to say that time doesn't exist, or that it is an independent thing, or that it is a dependent thing. To say that time exists doesn't tell us, for instance, whether time passes. To determine whether time passes, we need to know what time is like. As it turns out, there are only two theses about what time is like that the taxonomy needs to include.

In discussing a spatializing account of time, Ted Sider (2005) gives three theses that are discussed often in the philosophy of time:

- Eternalism (E)
- Reductionism about tense (T)
- Reductionism about the direction of time (D).

These three theses provide a good guide to discussing how to further divide logical space, though only T and D are required for a complete theory of time. I will discuss each in turn.

2.2.1 Eternalism

Eternalism is a thesis about temporal things. There might be non-temporal things; if there are, they are of no concern when discussing eternalism. I'm not going to dwell on what makes a thing temporal. A rough guide is that something is

[2] This might seem forced if you think that there is exactly one thing: could there be exactly one thing that is a dependent thing? There cannot, but we can still make sense of these categories if there is only one thing. Perhaps, as a matter of fact, the one thing exists all on its own, but it could have existed alongside something else and depended on it. If you reject grounding necessitariansim—the view that things have their grounds necessarily—then this is a viable option. (Those who reject grounding necessitarianism include (Schaffer 2010c) and (Schnieder 2006).) Moreover, the fact that one category of things has no members is not a mark against the partition: one would be in an analogous position if one thought there were, necessarily, only independent things—but such a view doesn't seem a mark against the partition.

temporal provided that it has temporal properties or enters into temporal relations. It's likely that there are ways to clarify or define the term, but its meaning seems clear enough to proceed.

As Sider puts it, eternalism is the view that "events, times, and objects from the past, present, and future are equally real" (Sider 2005, 330).[3] This captures the spirit of eternalism, but those attracted to a spatializing view of time or to a B-theory of time might find the appeal to the past, present, and future troubling in this statement of eternalism, since spatializers and B-theorists see the distinction between past, present, and future as metaphysically unimportant. In this respect, Ned Markosian's statement of eternalism is much better: "According to the Eternalist, temporal location matters not at all when it comes to ontology" (Markosian 2014, S6).

The aforementioned characterizations of eternalism capture the spirit of what Baron and Miller call the ontic component of eternalism: "the ontology of the world does not change" (Baron and Miller 2013, 33). One way to express this view more rigorously is to talk about eternalist worlds. For instance, one way to express the eternalism's ontic component is:

> w is an eternalist world only if (A) w is such that for every time t that exists in w, there is a set S of times $t_1, \ldots, t_n$ such that at every t, all and only the members of S unrestrictedly exist or (B) w is such that for every space-time point p that exists in w, there is a set S^* of space-time points $p_1, \ldots, p_n$ such that at every p, all and only the members of S^* unrestrictedly exist. (37–38)

Baron and Miller note that a definition of eternalism also requires "some sort of commitment to the *B-series*" (39). The B-series uses the relations *is earlier than*, *is later than*, and *is simultaneous with* to order times, object, events, or spacetime points. They note that "most philosophers who self ascribe as eternalists" accept something like the following: "w is an eternalist world only if there is an exclusive

[3] See also (Tallant 2008).

B-series ordering of events in w, such that the ordering of those events is both linear and asymmetric (Baron and Miller 2013, 46)". A B-series is exclusive "just in case necessarily, for any world w in which there is a B-series, there is not also an A-series" (45). Accepting both the ontic component and exclusive B-series, as described by Baron and Miller, is not the only way to be an eternalist. Baron and Miller offer several other options for both the ontic component and the level of commitment one can have to the B-series but do not argue for one particular statement of eternalism; instead they conclude by stating that they "have outlined a range of views that are, when all is said and done, very different from one another" (63).

I'm not concerned with which of the several ontic components offered by Baron and Miller is the best ontic component for an eternalist to adopt. I'm also not concered with what level of commitment to the B-theory an eternalist should adopt. What I am concerned with is something that Baron and Miller quickly pass over in a footnote: the difference between using times, events, and objects to define eternalism (39-40, fn. 6). Just as different versions of the ontic component and different levels of commitment to the B-series yield different versions of eternalism, using different things to define the ontic component and level of commitment to the B-series will also yield different versions of eternalism. I'm going to argue that any complete view of time must accept some version eternalism and that other varieties of eternalism are irrelevant to one's view of time. This has two consequences. The first consequence is friendly to presentism: one can have a complete view of time without being an eternalist about objects. The second consequence is that we need not consider eternalism in our taxonomy since every view of time needs to accept some variety of eternalism. In the arguments that follow I will use "temporal location" as a neutral term.

A view of time must underwrite temporal semantics. On an adequate temporal semantics, statements such as "Lincoln was president after Washington" are true.

These kinds of statements invoke a temporal relation that refers to individuals who did not exist at the same time. A safe view about relations is that relations can only be instantiated by relata that exist. So, whatever these things are, they need to exist in order to have true statements that mention temporal properties and relations. This requires existence irrespective of temporal location, which is just to say that it requires eternalism of some sort. To put the point another way: in order to underwrite an adequate temporal semantics, a view of time must have distinct temporal locations that are all equally real.[4] There is an important question about how we get content for different temporal locations; in answering this question other forms of eternalism may come into play. But here I am concerned to show that the question of *whether* eternalism about some thing is true must be answered affirmatively if a view of time has the resources to underwrite an adequate temporal semantics. An important consequence of this claim is that we need not take a stance on eternalism about objects in order to give a worked-out view of time.

One might object that no form of eternalism is friendly to presentism (or the A-theory) if the B-series is exclusive, since some presentists (and A-theorists) think that one can have both an A-series and a B-series in the same world. Rather than argue against an exclusive view of the B-series, I want to note that whether a version of eternalism is presentist-friendly depends on what we are ordering with the B-series, or what we are using to state the ontic commitment of eternalism. If we are using objects to state both components of eternalism, then yes, eternalism is not presentist-friendly. But if the B-series orders, say, times, that does not mean

[4] Lest you think something fishy is going on here, note that one cannot state eternalism unless one admits temporal locations. If these locations are not parts of time, then the most sensible conclusion is that time is not a thing, in which case the question of eternalism about time is moot. So, assuming that time is a thing and that we want to know whether eternalism about time should be a part of our taxonomy, we must assume that time has parts, namely, temporal locations.

that there cannot be an A-series defined over objects—at least you don't get that inference for free.

In most discussions, the scope of eternalism covers events, times, and objects. I've argued that eternalism should not be included in the taxonomy being developed. Nor need one include eternalism about events, times, and object. The varieties of eternalism speciate views of time; but you need not endorse one particular variety of eternalism—specifically, you need not endorse eternalism about objects—in order to have a worked-out theory of time.

2.2.2 Reductionism About Tense

Up next we have reductionism about tense. The debate about tense amounts to the following. We make tensed statements in ordinary language. These statements suggest that time has a dynamic character, that time passes or moves. Tensed statements are supposed to represent how reality changes, how time passes or moves. The debate about tense is whether such statements are faithful (or accurate) representations of reality, i.e. whether we need tensed statements to have a complete description of reality. Those who endorse reductionism about tense say "no": reality can be represented solely in tenseless terms; tensed statements can either be translated into tenseless statements or discarded entirely, and our description of reality will not be incomplete. Those who deny reductionism about tense hold that tenseless statements are not enough: even if we can describe most of reality in tenseless terms, we still need some irreducibly tensed statements to complete the description.

What it means for a statement to be irreducibly tensed requires some clarification. Kit Fine (2005) offers a systematic way to approach this debate, one which shows how time could be tensed, if it is. Fine says that, with respect to tense, there are four theses one can hold:

Realism: Reality is composed of tensed facts.

Neutrality: No time is privileged.

Absolutism: The composition of reality is not irreducibly relative.

Coherence: Reality is not irreducibly incoherent.

To deny reductionism about tense, one affirms Realism along with two of the three remaining theses, and rejects the remaining one.[5] It is Realism that does all the work for settling whether you are a reductionist about tense; the other three theses specify what kind of anti-reductionist you are, if you endorse Realism. For if reality is composed of tensed facts—i.e. if the fundamental constituents of the world are tensed facts—then you cannot reduce those tensed facts to tenseless ones.[6] Thus, we arrive at a denial of reductionism about tense.

Fine's approach to the debate about tense allows us to clarify what it means to say that a statement is irreducibly tensed. According to the standard way of denying reductionism about tense, statements about which time is privileged are irreducibly tensed. Assuming that which time is privileged changes, the only way to state what time is privileged must be tensed. Any attempt to translate such a statement into tenseless terms ends up yielding a tautology—e.g. "At t_1 it is t_1"—and such tautologies do not capture an important part of reality. So, a description of reality that does not include "It is (now) t_1" is incomplete.

That there are different ways to deny reductionism about tense is no surprise, just as it is no surprise that there are several ways that reductionism about tense

---

[5] Fine argues that McTaggart's argument against the reality of time (McTaggart 1908) aims to show that one cannot coherently hold all four theses. The standard view one adopts when one rejects reductionism about tense is a view that affirms Realism, Absolutism, and Coherence, but rejects Neutrality. Fine ultimately argues for a view call fragmentalism, which accepts Realism, Neutrality, and Absolutism, but denies Coherence. However, any combination of these theses is possible. See (Lipman 2015) for a critical discussion of Fine's fragmentalism.

[6] Reductionism about tense is a thesis about language, and Fine's four theses are not about language, so this is not quite correct as stated. In Fine's official idiom, we state this by appealing to sentences that express tensed facts, sentences that express tenseless facts, and a sentential operator R. For any sentence ϕ, $R\phi$ is read as "In reality, ϕ". Let τ be some sentence expressing a tensed fact. If $R\tau$ is true, then reductionism about tense is false.

could hold. Isn't it important *how* reality is tensed, or *how* tensed statements can be reduced to tenseless ones, not just *that* this is the case? Yes, how reality is tensed or not is important, but it should not be a part of our taxonomy. The short reason is that we have to draw the line somewhere, lest we admit so many distinctions that our taxonomy become too cumbersome. A taxonomy should have some heuristic value; admitting too many details makes that impossible; so, we must omit some information. I've chosen to use independence, reductionism about tense, and reductionism about the direction of time for three reasons. First, they are relatively familiar and employed often, whereas some of the distinctions in how reality could be tensed or not are not. Second, a taxonomy that appeals to these three theses subsumes both the A-theory/B-theory debate and the substantivalism/relationalism debates and neither of those debates subsumes the other (so, this taxonomy offers a way of relating different debates). Third, regardless of whether time exists or not, we can ask whether either of reductionism about tense is true or reductionism about the direction of time is true;[7] this kind of mirroring makes for a clean presentation that has heuristic value and allows for easy comparison of rivals views.

2.2.3 Reductionism About The Direction of Time

Finally, there is reductionism about the direction of time. Sider notes that one who endorses this thesis might say that the direction of time reduces to the direction of causation or to "some asymmetry in matters of particular fact such as entropy" (Sider 2005, 330). While these are helpful examples of how one can endorse this thesis—i.e. they are helpful examples of *how* the direction of time is reducible to something else—the examples don't tell us enough about what it means for time to have a direction. We can clarify the idea, though.[8] To say that time has a direction

---

[7] I discuss how this is possible below when I talk about possible views of time.

[8] Thanks to Alexander Pruss for helping me clarify my clarification here.

is to say that time has a certain kind of order, one which says that it "goes" this way rather than that. An intuitive way to accomplish this is to say that time is a set of times, and these times are ordered by a relation that is at least asymmetric. (If time is linear, the relation should be transitive as well. If we include only those times that were, are, or will be present in our set of times, then the relation should also be total.) Moreover, we want to this relation to be natural. In this context, the question of reductionism about the direction of time is one about what induces such an ordering on the set of times. For instance, it might be causation that orders time: time goes this way rather than that because causation goes this way rather than that. If that's the case, the ordering relation is explained by the causal nexus: that the set of times has the order it does is explained by (and grounded in) the causal nexus. If we find that there is nothing like causation or entropy that induces the right kind of ordering relation, then reductionism is false: the direction of time is intrinsic to time itself. In this case, if the set of ordered times is a representation of time, that there is a certain ordering relation on the set of times is a brute fact. (As with tense, we are now at a point where we can go further and explore the ways in which time's direction is reducible, or how time could have an intrinsic direction; but such an exploration would take us too far afield for present purposes.)

2.2.4 Possible Views of Time

I've offered taxonomy of possible views of time. This taxonomy, I claim, does a better job of expressing possible views of time than either of the two main debates in the philosophy of time: that between substantivalists and relationalists, and that between A-theorists and B-theorists. I'm now going to offer all the possible views of time and then, in the next section, show where several positions within the philosophy of time land.

Above I pointed out three theses that are crucial to having a complete theory of time. The first thesis is about time's existence: is time an independent thing, a dependent thing, or nothing at all? The other two theses are about what time is like. The first of these theses is reductionism about tense; the second is reductionism about the direction of time. This yields twelve possible views of time. To make it easy to keep track of who holds what view, I'll adopt the following convention. "N" will name the thesis that time is not a thing, i.e. that it does not exist. "I" will name the thesis that time is an independent thing, while "$\overline{I}$" will name the thesis that time is a dependent thing. For the other two theses, "T" will name the thesis that tense is reducible, and "D" will name the thesis that the direction of time is reducible; $\overline{T}$ is the denial of T and $\overline{D}$ is the denial of D. In naming views, I will always put the thesis about existence first; the theses about tense and the direction of time will come second and third, respectively. Putting this all together, ITD is the spatializing view of time mentioned above. I defend the $\overline{I}\overline{T}D$ view of time.

Here is a good place to pause and make a few remarks on where some views fall in my taxonomy. These remarks will make it clear that each set of opposing views does not, on its own, offer a taxonomy of views. The opposing views I have in mind are relationalism and substantivalism, the A-theory and the B-theory, and realism, anti-realism, and idealism. Traditionally, the distinction between substantivalists and relationalists has been that substantivalists endorse I while relationalists maintain $\overline{I}$. I will say more on the A-theory/B-theory debate below, but one major dividing line between A-theorists and B-theorists is whether T is true. It is common to label someone an A-theorist if they think that T is false, while someone who believes that T is true is often considered a B-theorist. Finally, there is realism, anti-realism, and idealism. The difference between realism and anti-realism is easy enough to state: anti-realists endorse N while realists deny it.[9] The distinction between realists and idealists is more slippery. Idealists don't deny that there is such a thing that is called "time", but they do hold that it is somehow different than other things. In my discussion of Leibniz, we'll see that the way in which time is different, on the idealist picture, depends on one's view of dependent things.

2.3 Philosophy of Time: Past and Present

I've just offered a way to carve up logical space with respect to views of time. One should want to know both (a) should we care about such a partition and (b) is it exhaustive? To both questions I answer affirmatively. That my taxonomy is exhaustive is guaranteed by the ways in which it was set up. That we should care about such a taxonomy is shown by demonstrating how the taxonomy offers a way to unify views of time that have been been offered. Above I offered a big-picture view of the philosophy of time which showed that answering one of the major debates is not enough to provide a complete theory of time. We now go from the forest to the trees. In what follows Aristotle and Leibniz are the main focus, since my view is a descendent of their views, though several figures who oppose their views are considered too.

2.3.1 Eleatics and Atomists

Parmenides, Zeno, and the Atomists serve as a useful background against which to view Aristotle's theory of time. My exposition of their views paints in broad strokes, relying on the work of commentators.

---

[9] The anti-realist can still take a stand on T and D provided that she believe in times or temporal relations or some related thing. For instance, if she believes in times, she need not believe in time so long as she denies that times compose a whole or she denies the existence of sets (thus denying that time is the set of times). Thanks to Alexander Pruss for pointing this out to me. For one example of one kind of anti-realism see (Baron and Miller 2014).

Parmenides and Zeno can be seen as a philosophical duo.[10] A prominent historical narrative of these two is that Zeno is the defender of Parmenides' views. Parmenides espoused the doctrine of ontological monism—the thesis that there is only one thing—and Zeno defended it against criticism by showing that ontological pluralism—the thesis that there are multiple things—leads to contradictions. Parmenides held that change is an illusion, and Zeno defended the view from criticism by offering paradoxes that arise from the assumption that there is motion. John Palmer points out that this narrative attributes two theses to the Parmenidean metaphysic:

> T1: There is exactly one thing that exists, and this unique entity is both spatially and temporally undifferentiated.
> T2: The world of ordinary experience is a non-existent illusion and sensory evidence for its existence is radically deceptive. (Palmer 2009, 17)

The narrative is not without dissenters, with Palmer as one of them.[11] Be that as it may, there is still a consensus that Parmenides held some form of monism—even if it is not the strict form of monism in T1. Parmenides did say, after all, that what exists is whole, it is "all together one, continuous" (Curd 1996, 47).

I'm not going to take sides on the correct way to interpret Parmenides. Even if Parmenides did not hold T1, Melissus, another Eleatic philosopher, can be credited with holding the view (Palmer 2009, 207). So long as someone held T1 and T2, it is worthwhile to see what these theses tell us about time.

T1 arbitrates whether time is an independent thing. If T1 is true, then "all the world is an unchanging, timeless unity" (Bardon 2013, 9). To say that time exists would require either that time is the one thing or that time is a dependent thing. It is implausible that time is the one thing, i.e. the whole. If time is a dependent

---

[10] See Plato's dialogue *Parmenides*.

[11] Some of the dissent comes from disagreement about T1 and T2; Palmer, for instance, thinks that T1 is too strong. There is also disagreement about the relationships between Parmenides and other ancient Greeks.

thing, it must be a (proper) part of the whole since there is only one thing; but then the whole is temporally differentiated, which violates the second conjunct of T1. So, if T1 is true, (at least one of) the Eleatics denied I.

T2 informs us about T and D, and tells us that, if time exists, time is a dependent thing. "Non-existent illusion" is a misleading phrase. One way to clarify it is to talk in terms of fundamentality: illusions exist, but they are not fundamental; they are not a part of the unchanging, timeless unity that is the world. This leaves us with two readings of the Eleatic's view time. On the first, tense and the direction of time are reducible to appearances, but time does not exist because appearances are not dependent things. On the second reading, we have the same reductive picture of tense and direction, but time exists because appearances are dependent things (and depend on the whole). As with other idealists, whether this reading is plausible depends on one's metaphysics of appearances. Since I am not discussing the metaphysics of appearances, I will only note this possible reading and move on. So, the Eleatics likely held NTD, but could be read as holding $\overline{I}TD$.

There are not many extant metaphysical works from the Atomists. But from what we do have from the Atomists, it looks like they (or at least Democritus) held that time is an independent thing. The Atomists had three kinds of metaphysical entities: atoms, the void, and the vortex. Even though they labelled the void "what-is-not," they clearly saw it as something, since the void is that in which atoms move. Furley (1976) notes that the Atomists held that the void is necessary for motion: there needs to be something in which the atoms can move, if they are to move at all.[12] Insofar as movement requires time, one can read the Atomists in a way consistent with a view of time on which it is an independent thing. This is a bit of a stretch, since the most natural interpretation of the void is that it is some kind of spatial

[12] Not that the atoms move themselves in the void; the atoms don't have causal powers. Rather, it is the vortex that is responsible for making the atoms move. See (Furley 1976).

container. Nonetheless, it is interesting to note that Democritus likely considered that time is an independent thing long before Newton, the paradigm proponent of the view. Beyond this is it hard to say where exactly the Atomists land in the above taxonomy.

2.3.2 Aristotle

In *Physics* IV Aristotle puts forward his theory of time.[13] The view of time that he proposes is that time is "the number of motion in respect of before and after" (219b2).[14] I'll first discuss what it means to say that time is a kind of number. This will lead to a discussion of what time is like: once it is clear what it means to say that time is a kind of number, we are led to ask about other terms connected to time, such as "present" and "instant".

For Aristotle, "number" has two senses: something can be a number because it is that which is counted; or something can be a number because it is that by which we count (219b5–9; cf 220b8–9). The latter sense of "number" is one that is familiar: as we normally think of them, numbers are those things with which we count. To say that a number is that which is counted is not as familiar, but what Aristotle means is that a number is a unit. This is a perfectly familiar idea: as Julia Annas puts it, "To count a group of objects we first have to pick out something to count as our unit; we have to know what we are counting" (Annas 1975, 99). Meters, seconds, horses, fir-dogs, and trout-turkeys can all be used as units, and therefore as numbers. But when we take, say, horses as our unit, "a horse" does not designate a specific horse, just as "a meter" does not designate a specific meter. To invoke terminology from medieval logic, we are using "horse" syncategorematically

[13] Van Fraassen (1970) concludes that "Aristotle's theory of time is basically a theory of duration" (17). His main reason is that a theory of time needs to give an account of temporal order, but Aristotle uses one relation of temporal order, that of simultaneity, in order to tell us what time is.

[14] All Aristotle quotations are taken from (Aristotle 1984) unless otherwise noted.

rather than categorematically.[15] Norman Kretzmann offers a succint statement of the difference between the two kinds of words: "Any word that can be used alone as a subject term or as a predicate term is classifiable as a categorematic word; all other words are classifiable as syncategorematic words" (Kretzmann 1982, 211). Note that this is a syntactic distinction.[16] These categories are not exclusive: some words can be used both categorematically and syncategorematically. To make it clear that I am using a word syncategorematically, in what follows I will write the word with small caps: "HORSE" signals a syncategorematic use, "horse" is a categorematic use.

When we are (or, when Aristotle was) concerned with numbers, ONE is that which is counted, i.e. we count by ONEs; ONE is the "measure of number" because it is the appropriate unit of measurement.[17] But we can also use "one" categorematically: "One is the loneliest number." This reveals an ambiguity in Aristotle's definition of time. "Time" can also be used both categorematically and syncategorematically. We say things like "Building a house will take a long TIME." If we're talking about TIME, then we can read Aristotle's definition as an attempt to clarify the rules of use:

SYN: TIME is a unit, and it is that which is used to number motion with respect to before and after.

On the other hand, "the number of motion" might refer to some totality as "the number of people" does. In this case, the "is" in Aristotle's definition is being used

---

[15] Thanks to Alexander Pruss for bringing this distinction to my attention.

[16] Henry of Ghent has a nice statement of what goes on semantically with syncategorematic words: "And they are called syncategorematic as if to say 'consignificant';—i.e., significant together with others, namely, with categoremata—not because they signify *nothing* on their own, but because they have a signification that is not definite but indefinite, a signification whose definiteness they derive from those [words] that are adjoined to them. For they do not signify any *thing*, but they signify rather in the manner of a disposition of a thing and of terms signifying things. Every disposition, however, is indefinite in itself and is made definite by that which it disposes" (quoted in (Kretzmann 1982, 213–14)).

[17] Annas adds to this that Aristotle explained counting in terms of measurement. See (Annas 1975, 99).

to identify time with some thing. On this reading Aristotle is saying something such as:

CAT: Time is the sum of all of times, where times are instances of TIME, the unit used to number motion.

CAT is one, and certainly not the only, categorematic reading of Aristotle's definition. Whether Aristotle endorsed something like CAT determines whether he thought that time is some thing.

Even though we can use it syncategorematically, "time" is not often thought of as a unit. We do not talk of a hike taking five TIMEs. But there are temporal units that we count: SECONDs, MINUTEs, etc. We find something similar when we consider LENGTH. A plank of wood is not seven LENGTHs; it is seven METERs or 700 CENTIMETERs. In both cases it seems that there is a genus-species relationship between syncategorematic terms: TIME is the genus, MINUTE and SECOND are the species; LENGTH is the genus, METER and CENTIMETER the species.

Saying that TIME is a genus clarifies what Aristotle means when he says that TIME is the measure of motion. But there is still a question of where the species come from. How do we decide which units are appropriate temporal units? For Aristotle, part of the answer comes from his definition: we need something that can measure motion in respect of before and after. The phrase "motion in respect of before and after" is a way of talking about change. W. von Leyden notes that "before" and "after" have two senses for Aristotle. When using "before" and "after" as a way of referring to a "phase" of a substratum (i.e. an earlier state and a later state of a substratum), before and after are "the same as movement" in that we use the terms to signal a change in a substance that we want to measure; but when we think of before and after as relations like *is earlier than* and *is later than*, they are not (Von Leyden 1964, 49). In Aristotle's definition of time it is clear that we are concerned with "before" and "after" as referring to the different phases of a substratum; that is, we are concerned with the motions and changes of substances. So, the species of TIME are those units that can measure motion.

Aristotle's cosmology affords him a way to specify such a unit. The heavenly spheres exhibit uniform circular motion.[18] Given this, all motion and change is to be measured with respect to the circular motion of the heavens (223b12–224a2).[19] Aristotle does not specify any particular unit of measurement, but it is clear that he thinks there is at least one such unit. Perhaps, for instance, we use a complete rotation of the inner sphere to get the unit C-ROTATION. We can then say that Bill has lived for ten C-ROTATIONs. Given his cosmology, this is a satisfactory way to choose a unit of measurement; a modern take on Aristotle's view will need some other method, which is a challenge I take up in chapter five.

Aristotle does not deny the existence of numbers. So it is clear that he at least endorses SYN. But it is not as clear whether he endorses CAT. It is clear that time is not an independent entity or a substance (since numbers are not). If Aristotle did hold that time exists, then he endorsed $\overline{I}$. But whether he held that time exists

---

[18] It is (slightly) inappropriate to talk about uniformity since this term has a meaning relative to some reference class. The reference class determines what is uniform. So, when we are deciding on a reference class with which to define "uniform", we cannot appeal to "regular motion" or "uniform processes". In Aristotle's case, this means that he has to stipulate that the heavenly spheres have uniform locomotion.

[19] The first part of the text is worth quoting in full, since it fills out the picture of number offered above:

> Now there is such a thing as locomotion, and in locomotion there is included circular movement, and everything is measured by some one thing homogeneous with it, units by a unit, horses by a horse, and similarly times by some definite time, and, as we said, time is measured by motion as well as motion by time (this being so because by a motion definite in time the quantity both of the motion and of the time is measured): if, then, what is first is the measure of everything homogeneous with it, regular circular motion is above all else the measure, because the number of this is the best known. Now neither alteration nor increase nor coming into being can be regular, but locomotion can be. This also is why time is thought to be the movement of the sphere, viz. because the other movements are measured by this, and time by this movement (223b12–24).

cannot be answered until we look further at Aristotle's view on instants, which will also touch on Aristotle's take on T and D.

I have not given any kind of defense of Aristotle's view about what time is, and I do not intend to. Instead I am going to turn to questions about what time is like, giving special consideration to the ideas of the present and instants, two concepts that are conspicuously absent in the preceding discussion of Aristotle's view. Motion, instants, and the present each figure into Aristotle's discussion of time, but only the first has a place in his definition of time. As we've seen, *that* time—or at least TIME—exists is due to the fact that there is motion; were there no motion, there would be nothing to measure, and thus no TIME. Aristotle's views of instants and the present tell us what time is like and make clearer whether Aristotle held that time exists. In explicating what time is like, we will see some of the rationale behind considering time as a kind of number. We will also see why Aristotle held neither that time is identical to motion nor that time is composed of instants.

One reason for holding that instants are not a part of time is that supposing that they are leads to trouble, when we also hold that there is motion. In *Physics* IV, Aristotle presents three arguments against the existence of time. The first is:

> One part of it [time] has been and is not, while the other is going to be and is not yet. Yet time—both infinite time and any [stretch of] time you like to take—is made up of these. One would naturally suppose that what is made up of things which do not exist could have no share in reality. (218a2–3)

Aristotle's second argument is:

> Further, if a divisible thing is to exist, it is necessary that, when it exists, all or some of its parts must exist. But of time some parts have been, while others are going to be, and no part of it *is*, though it is divisible. For the "now" is not a part: a part is a measure of the whole, which must be made up of parts. Time, on the other hand, is not held to be made up of "nows". (218a4–8)

And the third argument is:

> Again, the "now" which seems to bound the past and future—does it (i) always remain one and the same or is it (ii) always other and other? It is hard to say. (i) If it is always different and different, and if none of the *parts* in time which are other and other are simultaneous (unless the one contains and the other is contained, as the shorter time is by the longer), and if the "now" which is not, but formerly was, must have ceased to be at some time, the "*nows*" too cannot be simultaneous with one another, but the prior "now" must always have ceased to be. But the prior "now" cannot have ceased to be in itself (since it then existed); yet it cannot have ceased to be in another "now". For we may lay it down that one "now" cannot be next to another, any more than a point to a point. If then it did not cease to be in the next "now" but in another, it would exist simultaneously with the innumerable "nows" between the two—which is impossible. (ii) Yes, but neither is it possible for the "now" to remain always the same. No determinate divisible thing has a single termination, whether it is continuously extended in one or in more than one dimension; but the "now" is a termination, and it is possible to cut off a determinate time. Further, if coincidence in time (i.e. being neither prior nor posterior) means to be in one and the same "now", then, if both what is before and what is after are in this same "now", things which happen ten thousand years ago would be simultaneous with what has happened to-day, and nothing would be before or after anything else. (218b9–29)[20]

Notice that in each of these arguments, we arrive at a problem because we suppose that there is motion and that the present is a part of time. By holding that time is a kind of number, and not composed of instants, Aristotle has an easy way out of these arguments—irrespective of whether his view is tenable.[21]

Given that time is a kind of number, Aristotle has another reason to hold that time is not composed of nows. In *Physics* VI.3, Aristotle states that "Necessarily,

[20] Numbering added. Inwood (1991) notes that Argument 2 is really a supplement to Argument 1.

[21] That last phrase matters, of course, for whether Aristotle's way out of these arguments is of any interest. Inwood concludes his paper by saying that Aristotle's answer to the arguments against time's existence "is involved and often obscure and ambiguous, but it is neither negligible nor obviously incorrect" (178). Inwood argues that Aristotle's answer is not just the denial of the claim that time is composed of instants, but also involves a positive account of what the now is.

too, the now—the now so-called not derivatively but in its own right and primarily—is indivisible and is inherent in all time" (233b33–34). The argument is about the primary use of "now" since (as Aristotle recognized) we sometimes use "now" to refer to a period of time (as in "It is now 2016"). Aristotle is not here concerned with the derivative uses of "now"; here he is concerned to show that indivisible instants are not a part of time. Here is the argument:

> For the now is an extremity of the past (no part of the future being on this side of it), and again of the future (no part of the past being on that side of it): it is, we maintain, a limit of both. And if it is proved that it is of this character and one and the same, it will at once be evident also that it is indivisible.
> Now the now that is the extremity of both times must be one and the same; for if each extremity were different, the one could not be in succession to the other, because nothing continuous can be composed of things having no parts; and if the one is a part of the other, there will be time between them, because everything continuous is such that there is something between its limits described by the same name as itself. But if the intermediate thing is time, it will be divisible; for all time has been shown to be divisible. Thus on this assumption the now is divisible. But if the now is divisible, there will be part of the past in the future and part of the future in the past; for past time will be marked off from future time at the actual point of division. Also the now will be a now not in its own right, but derivatively, for the division will not be a division in its own right. Furthermore, there will be a part of the now that is past and a part that is future, and it will not always be the same part that is past or future. Nor, then, will the now be the same; for the time may be divided at many points. If, therefore, the now cannot possibly have these characteristics, it follows that it must be the same now that belongs to each of the two times. But if it is the same, it is also evident that it is indivisible; for if it is divisible it will be involved in the same implications as before. It is clear, then, from what has been said that time contains something indivisible, and this is what we call the now. (233b33–234a23)

Inwood (1991) is not impressed with these arguments for establishing that the now is an indivisible instant. Nonetheless, whether the arguments are (or can be) successful is beside the point since I am only sketching, not evaluating, Aristotle's view. And it is clear that Aristotle held that the now is an indivisible instant.

If the now is an indivisible instant, then the now (and any other instant) cannot be a part of time (see 218a8). Owen points out that "any part must serve to measure the whole of which it is a part" (Owen 1976, 10). But given that nows are indivisible instants, they cannot be used to measure. Here Aristotle is relying on an analogy with lines. As Owen puts it, "The present is like the point, and lines are not collections of points" (11). While we may talk of lines as collections of points, we do not measure lines by points: there are simply too many of them.[22] Instead we choose something else as a unit, and use that as our way of measuring the length of a line. So too with time; there are too many nows to be able to measure time; so we choose something else (the motion of the heavens, for Aristotle) as our unit of measurement. Since nows cannot be a measure of time, nows (and instants more generally) are not a part of time. This has the interesting consequence that it is slightly misleading to talk of time as a line. TIME is, recall, a unit of measurement; it is not a part of some container in which events happen. Nonetheless, a line does *represent* time in the same way that a ruler represents a spatial unit of measurement. Moreover, SYN is still a viable thesis for Aristotle: it is only indivisible instants that cannot compose time, and times (which are perhaps instances of a TIME) are not indivisible instants.

While the present is not a part of time, it nevertheless serves as the boundary between the past and the future (233b33). This is the first half of Aristotle's answer to the second argument against the existence of time. As a boundary between the past and the future, the present is always the same. But as a particular instant, the

[22] This will be explored more in the subsequent chapter, but it's worth mentioning here. The idea that the points of a line are too numerous (or too short) for establishing a metric—since that's why we pick a unit of measurement—ends up having interesting consequences for the relationalism/substantivalism debate. If we can't count with the points, then it seems gratuitous to posit them as real entities, which is evidence against substantivalism (note the epistemic premise there). One option is to go unit-less—and on that Bradford Skow (2010) has some interesting things to say about quantity—but that seems undesirable (except, perhaps, if we take a route that Field goes in *Science Without Numbers* (1980).

present is always changing. This dual nature of the present makes it seem as if the present is like an enduring object.[23] Mariña and Mason (2001) are right to point out that we should not take this analogy too seriously: if we do, the now ends up being something that exists independently of substances. But that is not how we should think of now.[24] Rather, we should think of the now as something that is linked to the moving thing.[25] This creates a slightly awkward position for Aristotle: if the now is linked to the moving thing, are there multiple nows? Aristotle surely wants to avoid saying that more than one now exists (otherwise Argument 3 resurfaces). For present purposes I am not concerned with how Aristotle resolves the difficulty; what matters is that Aristotle held that the now depends on the motion of objects. This suggests that Aristotle held (or would have held, had he thought about it) that the direction of time is reducible to the changes that substances undergo: going from one now to the next depends on how substances move and change.

There is one final point to note about Aristotle's view of time. We have just seen that Aristotle held that the now persists, and above I pointed out that Aristotle relies on an analogy with space to show that time is not composed of nows. (In fact, the analogy is fairly strong: Aristotle's view of time is based on his view of magnitude.[26] Owen (1976) takes this analogy as evidence that Aristotle held to the reality of the past and the future. Mariña and Mason (2001) seem to

---

[23] See, for instance, Inwood (1991).

[24] Inwood is clear on this point (contra Mariña and Mason (2001), 186): "In suggesting, though, that the now is analogous to an instantaneous state of the moving object rather than to the object as a whole, we are not only offending against Aristotle's reluctance to carve up objects along temporal lines . . . but also against the spirit of the persisting now" (Inwood 1991, 167).

[25] "Linked" is Mariña and Mason's term.

[26] See Inwood (1991): "Time follows motion, which in turn follows magnitude" (172, drawing from 219a10 ff and 219b15 ff). Cf. Annas (1975): "Aristotle argues that time is continuous because motion is, and motion is continuous because magnitude is. 'Before' and 'after' hold primarily of magnitude, derivatively of motion, and derivatively again of time" (107–108). Von Leyden's two sense of "before" and "after" need to be reconciled to this point.

disagree, in part because of the nature of the now; they argue that Aristotle held to a naïve version of the A-theory, which would make him deny reductionism about tense. On this matter I agree with Mariña and Mason, for two reasons. First, in *De Interpretatione* 9 Aristotle presents his famous sea battle example, and the moral from the discussion of future-tensed statements seems to be that some future-tensed statements are neither true nor false,[27] from which we conclude that some of the future is unsettled. If that's the case, it suggests that (at least) some objects and events are not as real as present and past ones. Second, insofar as the past and future are real, the reality seems best attributed to the measuring stick that represents time, not to the objects and events that are in time. Recall that the species of TIME, i.e. the temporal units that are counted, are determined by the regular motion of the heavens. But units are syncategoremata, which means that they do not require a referent in order to speak coherently of them. We can compare METERs and INCHes without anything extended in front of us. (The units do need to be grounded in some actual object, but through abstraction we can compare multiple units without a physical object in front of us.) Likewise, we can generate a timeline by considering consecutive C-ROTATIONs. Given that a complete view of time needs some way of talking about the future, it seems that Aristotle must have held that some kind of timeline exists, i.e. that time is a thing, and that it is made up of times. This along with the spatial analogy seem to grant the conclusion that we can talk of distances in the past or future but not of the existence of things or events in the future. If Owen means something like eternalism about objects by his claim, then he claims too much. But more importantly, we have reason to hold that Aristotle did endorse a thesis like SYN.

[27] It would be odd if Aristotle held that *all* future-tensed statements are neither true nor false: surely statements about the uniform motion of the heavens are true or false.

To sum up, Aristotle held that time is a kind of number, which lands him in the camp that says that time is not an independent entity. Within this camp, he held that the direction of time is reducible to the changes that substances undergo. We have not discussed whether Aristotle held to reductionism about tense, and here the previous paragraph is evidence that there is no clear answer on the matter. This leaves Aristotle holding $\overline{I}TD$ or $\overline{IT}D$.

2.3.3 Leibniz

We now take a leap forward to Leibniz. As I mentioned earlier, the view of time that I offer in chapter five is a descendent of both Aristotle and Leibniz. So, I want to take a look at their views especially. Prior to discussing Aristotle's view of time I brought up the views of some of his competitors. I will do the same with Leibniz's view, though the view of Leibniz's main rival, Newton, will come after a discussion of Leibniz's view of time.

In important respects, Leibniz continues on with the Aristotelian project. For Leibniz, much as for Aristotle, time is not something that exists fundamentally or independently of substances but rather is derivative. Leibniz has a hierarchical ontology that has at least two levels.[28] How many levels are present in Leibniz's ontology is not something that I will be concerned with here, since it seems that talking of discrete levels of abstraction is tricky at best, so the claim that we can neatly divide non-fundamental things into phenomenal and ideal seems slightly dubious to me. What matters (and is uncontroversial) is that there are at least two levels, the fundamental and the non-fundamental, and that time is not found on the fundamental

[28] Rescher (1979) and Mates (1986), for instance, hold the two level view, according to which there is the fundamental level and the phenomenal level. Some—such as Hartz and Cover (1988), McGuire (1976), and Winterbourne (1982)—hold that there are three levels to Leibniz's ontology: the fundamental, the phenomenal, and the ideal. Roberts (2003) claims to have a position that is intermediate between the two. I suspect that a part of the controversy rests on how we understand Leibniz's talk of space and time being some kind of order. If we need to go up a level of abstraction from the phenomenal to have such an order, the three-tier advocates are correct; if not, then the two-tier advocates or Roberts is correct.

level. Whether the non-fundamental can also be divided into discrete levels need not concern us. So, to the extent that a Leibnizian can say that time exists, its existence depends on more fundamental entites (monads and their changing modes, for Leibniz). Moreover, since time is derivative, it inherits (at least some of) its properties from the more fundamental things. It's clear that time depends on not only the monads, but also the phenomena to some extent.

Leibniz is seen as the paradigm relationalist. "Leibnizian relationalism" has come to be the name of the view that space and time are nothing over and above the spatial and temporal relations that hold between objects. Leibnizian relationalism attributes very little structure to space and time: the only quantities that can be defined are those that are relative; that is, there are no quantities such as absolute speed, absolute acceleration, and absolute direction. While one can maintain this position, it is unlikely that Leibniz was a Leibnizian relationalist. This will come out in the subsequent discussion as we see what Leibniz thought about eternalism, reductionism about tense, and reductionism about the direction of time.

Leibniz's view is a nice case of how one can deny eternalism about (fundamental) objects while still meeting the requirement that time can underwrite a semantics on which some claims about the past and future are true. One of Leibniz's more colorful phrases in the *Monadology* is that a monad's present is "pregnant with the future" (S22).[29] Leibniz had a mechanistic view of the world: one state of the world unfolds from its predecessors, and one with sufficient knowledge (i.e. God) can see how everything has been, is, and will be simply by looking at one monad (though what is seen would be from that monad's perspective). This does not mean that Leibniz was an eternalist about fundamental objects. The eternalist says that past, present, and future objects, things, events, etc., are all equally real. In a "flat" ontology—one on which no entities are derived from more fundamental ones—there

[29] Unless otherwise noted, quotes from Leibniz's works are taken from (Leibniz 1989).

is only one level of being that we need to consider. If eternalism is true with respect to the one level of being, eternalism is true *tout court*. But when we are dealing with a hierarchical ontology, as we are with Leibniz, then there are at least two levels of being, so we can ask whether eternalism is true with respect to each level. Thus, in Leibniz's case, we can ask whether eternalism is true about monads and whether eternalism is true about phenomena (and perhaps ideal things as well).

Leibniz's remark in S22 of the *Monadology* makes it easy to hold eternalism about phenomena. Since the future states will, with certainty,[30] come to pass, it does not seem a stretch to say that the present phenomena are equal in reality to the future and past ones. But even if that is true, it does not imply that eternalism is true about the monads, i.e. that there are past, present, and future monads (or monad stages), and that all of these monads are equally real. Leibniz is not clear about whether he holds to eternalism about monads. The way he speaks about monadic perception changing and causal interaction[31] might read slightly in favor of a denial of eternalism, but that is far from decisive. Nonetheless, one can read Leibniz in a way that denies eternalism about monads while offering a view of time that meets the requirement that a view of time of time can underwrite an adequate temporal semantics. One can unpack the statement that the present is pregnant with the future as saying that the present contains phenomena about the future, i.e. the monads now contain not only phenomena about the present but also phenomena about the future. One might say that the monads project future phenomena.

Leibniz did not explicitly address the question of whether tensed statements are irreducible to tenseless ones. While he appealed to tensed claims about what has been and what will be, that is no reason to suspect that he thought such state-

[30] Which is not the same as necessity on Leibniz's metaphysic. See S13 of the *Discourse on Metaphysics*.

[31] Really, quasi-causal interaction. See (Roberts 2003) and (Sleigh Jr 1990).

ments are irreducible. In fact, given his mechanistic worldview, it is likely that he thought tensed statements could be reduced to tenseless ones—at least for statements about phenomenal things. Reductionism about tense could only fail only for statements about monads. It might turn out that there are tensed statements about the monads, and any attempt to reduce those statements to tenseless ones results in an impoverished description of the world.[32] There is no indication that Leibniz thought that reductionism about tense fails for statements about monads. Consider the following remark that Leibniz wrote in 1712: "God sees things exactly as they are in accordance with the geometrical truth, although he also knows how everything appears to everything else" (Leibniz 1989, 199). What underlies this statement is Leibniz's view that monads have a perspectival view of the world. But God is able to see things exactly as they are:

> the distinction between the appearance bodies have with respect to us and with respect to God is, in a certain way, like that between a drawing in perspective and a ground plan. For there are different drawings in perspective, depending upon the position of the viewer, while a ground plan or geometrical representation is unique (199).

Note that this statement is about bodies, i.e. phenomena; it is not about monads. This suggests that it is statements about phenomena that are metaphysically important. If that's the case, then one could hold that statements about monads are irreducibly tensed and that, nonetheless, reductionism about tense is true. One can hold this view by denying that the irreducibly tensed statements about monads are not metaphysically important: a description of the world that left out such statements would be no more impoverished than one that included them.

Leibniz endorsed reductionism about the direction of time. What is interesting about what he reduces the direction of time to is that the reduction ends up giving

[32] This is true regardless of whether eternalism is true about monads. If eternalism is true, one can endorse eternalism and deny reductionism about tense by holding a view like the moving spotlight view suggested in (Broad 1923).

more structure to space and time than is present in Leibnizian relationalism. Roberts (2003) notes that the standard view of Leibnizian space and time (or spacetime) says that "the only well defined quantities of motion are the relative ones" (554). But, Roberts argues, the standard view is not what Leibniz actually held, since Leibniz held that there is such a quantity as absolute speed. And the thing that determines absolute speed shows us whence the direction of time is derived.

Leibniz's quantity of absolute speed comes from his concept of absolute motion. Absolute motion is change of location with respect to other bodies along with the causes of that change.[33] Relative motion is just change of location with respect to bodies. For Leibniz, including the cause of that change gives us absolute motion—and the cause of change offers an explanation for the direction of time.

Substances have derivative active force.[34] As Roberts notes, it is this force plus motion of the bodies (which appears at the phenomenal level) that yields living force, what Leibniz called "*vis vita*", which grounds absolute speed.[35] Given derivative active force, we have an elegant way to reduce the direction of time: the direction of time just is the order of the derivative active force, i.e. the order of the exercise of causal powers.[36] At the phenomenal level, it is the forces that determine how things change, and it is change that provides a direction to time. But we have a reduction of this whole process: "Living force is constituted by relative motions together with quasi-causal powers, and in turn determines what the true motions are" (569).

---

[33] See, for instance, Leibniz's "Critical Thoughts on Descartes" (in (Loemker 1989)). There is a second kind of motion—relative motion—that is mere change of spatial location.

[34] See "A Specimen of Dynamics" (pp. 117–137 in Leibniz 1989).

[35] As Roberts notes, this makes the spacetime structure "fully determined by the individual substances and their attributes" but it does not yield the Newtonian spacetime, since there can be absolute speed without absolute direction (559).

[36] This is a bit stronger than Leibniz could officially allow, given fn. 35.

To sum up Leibniz's view of time: time is not an independent entity. Moreover, of the two theses about what time is like, the only clear view that Leibniz upheld is reductionism about the direction of time. It is likely that he also held reductionism about tense as well, which means his view of time is $\overline{I}TD$.

2.3.4 Newton

The standard way of defining the substantivalism/relationalism debate pits Leibniz against Newton. Newton's main statements about absolute space and absolute time come from the *Principia*.[37] His main reason for positing absolute space and absolute time is theoretical. Newton had evidence that there is absolute motion and absolute motion, he thought, requires absolute space and absolute time.[38] For Newton, absolute time is an independent entity.[39]

Newton likely held view $IT\overline{D}$ from the above list. He likely held to reductionism about tense, given that his discussion of time in the Scholium makes no appeal to the past, present, or future. Yet he clearly held that the direction of time is *not* reducible to something else. In the first paragraph of Scholium I, Newton writes, "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration" (Huggett 1999, 118). Shortly thereafter, in Scholium IV, Newton writes that "All motions may be accelerated and retarded, but the flowing of absolute time

[37] All quotations are taken from the *Principia* are taken from (Huggett 1999).

[38] The most well-known piece of evidence is the rotating bucket experiment. Imagine a bucket filled with water that is suspended from the ceiling by a rope that has been twisted. If the bucket is allowed to rotate, initially only the bucket is in motion; the water remains still. But as the bucket continues to rotate, the water begins to rotate as well, receding from the axis of rotation, until the two are at rest relative to one another. Newton uses these two states to conclude that the water's motion away from the axis of rotation cannot be a matter of relative motion.

[39] Rynasiewicz (2014) notes that, though Newton's view is the paradigm of a substantivalist view, Newton did not think that time and time were substances but instead "real entities with their own manner of existence as necessitated by God's existence (more specifically, his omnipresence and eternality)" (Introduction).

is not liable to any change." Moreover, in paragraph VI of the Scholium, Newton states that "the order of the parts of time is immutable," and that "All things are placed in time as to order of succession." So, Newton holds both eternalism and reductionism about tense, but denies reductionism about the direction of time. And this is view $IT\overline{D}$.[40]

2.3.5 McTaggart and Beyond

We again take another leap in the history of the philosophy of time to discuss the debate that has taken the spotlight in contemporary discussions of time. In 1908, J.M.E. McTaggart published "The Unreality of Time" (McTaggart 1908). In that paper McTaggart talks about three different kinds of series: the A-series, the B-series, and the C-series. In the A series events have *properties* like *being present*, *being future*, *being near future*, etc. For the B series there are only *relations*: *is earlier than*, *is later than*, and *is simultaneous with*. Both the A series and the B series have a direction built into their order: the A series in virtue of the A properties and the B series in virtue of the B relations. The C series consists of *ternary predicates* such as "x is between y and z", and there is no direction in this series. McTaggart ventures to prove that time is unreal by showing that the A series is required for a proper time series, but that the A series is contradictory. What to make of McTaggart's argument has been a subject of debate,[41] but regardless of whether his arguments are any good, McTaggart's terminology has stuck around and framed a prominent debate in the philosophy of time.

---

[40] One could read this in a way that denies eternalism about material objects. Newton thought that space and time were containers, so he could have held that material objects are three-dimensional and move through time, analogously to the spotlight view, except the only things that are not illuminated by the spotlight and exist are space and time.

[41] Broad (1938), for instance, calls the argument a "howler" (316). B-theorists tend to see the arguments against the A-series in a positive light, but deny that the A-series is required for a proper time series.

McTaggart's distinction between the A series and B series began a debate between the A-theorists and the B-theorists. As you would expect, the difference between A-theorists and B-theorists comes down to the attitudes they have towards the A series and the B series.[42] But it turns out to be difficult to state that difference in terms precise enough to have a well-defined debate. That is, there is no agreed upon way to define the A-theory and the B-theory such that views are mutually exclusive and exhaustive, and the question of which view is true is not a merely verbal dispute. When I mentioned the A-theory/B-theory debate in my discussion of a taxonomy, I noted that one way of looking at the debate was in terms of tense. This characterization is mostly correct. But at the end of the day, it seems that the best way to approach this debate is as several debates about specific principles, and that one is an A-theorist or B-theorist by family resemblance.

There seem to be three ways to characterize the debate between A-theorists and B-theorists. The first is in terms of tense. A-theorists are said to "take tense seriously" since they hold that A-properties are real and irreducible. (For this reason, the A-theory is sometimes called "the tensed theory of time".) To "take tense seriously" is often read as a commitment to a privileged time, the present. To quote Dean Zimmerman on the point: the A-theorists "agree that the present is distinguished from past and future in a way that is not relative to any other temporal thing, such as a context of utterance, a time, or a frame of reference. 'B-theorists', by contrast, deny the objectivity of any such distinction" (Zimmerman 2005, 402). Or, to borrow an illustration from Alexander Pruss: if there were a book that contained all of the events in the world, knowing the contents of that book would make you omniscient were the B-theory true; but just knowing all of the events in the world

[42] Among the defenders of the A-theory we find Broad (1923), A.N. Prior (1970), P. Geach (1972), Adams (1986), Chisholm (1990), Bigelow (1996), Tooley (1997), Zimmerman (1998), Merricks (1999), Craig (2000a), Crisp (2003), and Markosian (2004). The ranks of the B-theorists include Quine (1950), Williams (1951), Smart (1963), Lewis (1976), Mellor (1981), Beer (1988), Le Poidevin (1991), Mellor (1998), Sider (2001), and Lewis (2004).

and how they are related with B-relations does not make you omniscient on the A-theory; on the A-theory, you also need to know which time is present.

Defining the A-theory and the B-theory in terms of whether there is a privileged time guarantees that the A-theory and B-theory are mutually exclusive. But there are two problems with this way of characterizing the debate. First, if this is all there is to the A-theory/B-theory debate, the debate seems too narrow to warrant the attention that it has received. To take tense seriously suggests that the debate is concerned with reductionism about tense. But the above characterization of the debate suggests that the debate is not even about that; rather, the A-theory/B-theory debate amounts to nothing more than a debate about the way in which reality is tensed (recall 2.2.2). That is still an important issue, but it seems like the debate is supposed to cover more than that. Second, it ignores an important ontological criterion of the B-theory: eternalism about objects. While A-theorists tend to deny eternalism about objects, one can endorse the A-theory and eternalism. An early attempt at this is (Broad 1923). More recently, Zimmerman (2005) and Sullivan (2012) have discussed the possibility of an eternalist A-theory.

The second way to frame the debate between A-theorists and B-theorists is in terms of property change. Rather than hold that taking tense seriously entails a statement about whether some time is privileged, one could instead hold that one who takes tense seriously believes in a certain kind of principle about property change. Meghan Sullivan offers two principles to capture the difference:

> A-Property Change: Objects do not require temporal parts or time-relational properties to undergo change. Some objects have temporary non-relational properties and endure through change.
>
> B-Property Change: Either all objects persist through change by having multiple temporal parts in the manifold or all objects change merely by instantiating varying relations to regions of

> spacetime. Nothing changes without temporal parts or varying spatiotemporal relations. (Sullivan 2012, 151)[43]

This way of characterizing the debate makes the A-theory/B-theory distinction seem less about time and more about objects. For instance, B-property change requires eternalism about objects. Insofar as we care about the A-theory and the B-theory of time, this way of characterizing the debate is inadequate.

Sullivan notes that the A-theory and the B-theory are not typically identified only according to one of the characterizations given. This leads to a third way to characterize the debate. Often A-theorists think their position involves both taking tense seriously and A-property change, while B-theorists hold that their view involves both the denial of a privileged time and B-property change. Defining each view as a conjunction of a thesis about tense and a thesis about property change better captures what philosophers take to be those views, but suggests that the distinction between the A-theory and the B-theory is no longer exhaustive (unless, of course, the two propositions in either conjunction are such that one implies the other).

And the distinction no longer is exhaustive if we define each view as a conjunction of theses. L. Nathan Oaklander (2012) defends a view that he calls the R-theory. The R-theory denies eternalism about objects (16). To deny eternalism about objects is to deny B-property change; so, the R-theory is not a version of the B-theory. But the R-theory is also a tenseless theory (5), which means that the R-theory is not a version of the A-theory.[44] So, if we define the A-theory and the B-theory in terms of a conjunction of views, the distinction is not exhaustive.

The above suggests that it is more profitable to view the A-theory/B-theory debate more as a debate about several topics related to time and less as a debate

[43] As Sullivan notes, B-property change admits of two varieties of the B-theory: temporal parts B-theorists and relational B-theorists.

[44] In the taxonomy, the R-theory is view $IT\overline{D}$. Oaklander endorses I on p. 4 and $\overline{D}$ on p. 5.

solely about time. The A-theory and the B-theory have a place on my taxonomy, but neither view is all there is to time.

2.4 Conclusion

In this chapter I've offered a taxonomy of views and illustrated it with historical examples. According to my taxonomy, there are three questions that a view of time needs to address in order to be complete. The first concerns the existence of time. There are three positions one could take: time doesn't exist (N), time is an ontologically independent thing (I), or time is an ontologically dependent thing ($\overline{I}$). The second question concerns tense. Here there are two options: tensed statements are reducible to tenseless ones (T) or not ($\overline{T}$). The third question is about the direction of time, and one can either affirm reductionism about the direction of time (D) or deny it ($\overline{D}$). I then employed this taxonomy in a discussion of several views of time. That discussion began with the Eleatics and Atomists. The Eleatics likely held NTD, but could be read as holding $\overline{I}TD$. The Atomists seemed to hold I, though not much more could be said about time given the limited number of extant writings. Aristotle and Leibniz held what is standardly called a relational view of time. Within the relationalist camp, Aristotle likely held to view $\overline{I}TD$ or $\overline{IT}D$ (though we saw reason to think that Aristotle could have held N instead of I), while Leibniz most likely defended view $\overline{I}TD$. Newton, the paradigm substantivalist, pretty clearly seems to have defended view $IT\overline{D}$. We then moved on to the A-theory and the B-theory. We saw that this debate is concerned with reductionism about tense, though the focus is more about how reality is tensed than whether it is, as well as ontological theses that are not solely within the province of the philosophy of time.

CHAPTER THREE

An Aristotelian Framework

In chapter two I said that there are two kinds of things: those that depend for their existence on other things and those that don't. In this chapter I say more about those kinds of things. The ontology that I consider is hierarchical: some things are more fundamental than others, and the less fundamental depend on the more fundamental. A key feature of this view is that anything that is not fundamental is an abstraction or a construction from what is fundamental. "Abstraction" and "construction" are terms of art here, and I discuss both after introducing the main ideas behind a hierarchical ontology. I then show how one can use abstraction and construction to determine whether a debate is substantive or amounts to a merely verbal dispute. The metaphysical framework I discuss in this chapter, which is Aristotelian in spirit, is what I will use to construct my view of time, respond to criticisms of my view, and critique other views in the remaining chapters.

3.1 The Chain of Being: Substances and Derived Things

The key components of the Aristotelian view I champion make use of substances, causal powers that are exercised, and an Aristotelian view of abstraction. Substances are at the bedrock of an Aristotelian ontology. Substances are independent entities, but not every independent entity need be a substance. Newtonian time, for instance, is not a substance because it lacks causal powers, but it is fundamental if it exists.

The independence that substances have from one another is ontological. That is, substances do not depend on one another for their existence. Only independent entities can be at the bedrock of the Aristotelian's ontology; everything else is derived from what exists at the fundamental level. For the moment it is important to say nothing more specific about what is at the fundamental level so as to keep from begging the question against certain views of time. It may be that the Aristotelian wants to have an entity like Newtonian time at the bedrock of her ontology. So, for the moment we should assume that the fundamental level of an Aristotelian ontology is comprised of ontologically independent entities. Arguing that time is not among these entities is a step that I will take in chapter seven.

Substances have causal powers. Causal powers allow substances to act. A substance can have causal powers without ever exercising them. As we will see, a derivation principle plus the claim that some substance exercises one of its causal powers is sufficient to entail the falsity of anti-realism about time. Since I am interested in putting forth a realist theory of time, I will assume that some substance does, in fact, exercise at least one of its causal powers.[1]

The Aristotelian framework I endorse has a hierarchical ontology that is ordered by a dependence relation. This yields a chain of being. Independent entities comprise the fundamental level of the ontology; every other entity is non-fundamental and ontologically depends on (or is grounded in) the independent entities, sometimes from only one independent entity, sometimes from several. I will say more about this below; for now Figure 1 will suffice to show how that hierarchy would look if there were one fundamental entity.

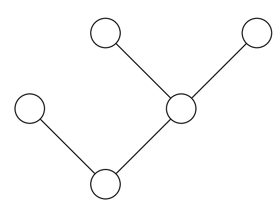

Figure 3.1. The Chain of Being

[1] As we'll see in chapter five, there is a thin line between the realist about time who thinks that time is a derivative thing and the anti-realist about time. One could say that there is some thing that plays all the roles of time yet that thing is not time, in which case one would be an anti-realist. I address this worry in chapter five when discussing the temporal metric.

The entities higher up on the chain of being are derived via abstraction or construction. Abstraction and construction are two species of derivation (or grounding). Abstraction can be thought of as stripping away or removing properties that a substance has. Construction can be thought of as putting together multiple substances or the properties and powers that some substances have. As Jonathan Schaffer puts it, the non-fundamental things are "already latent within the substances" (Schaffer 2009a, 375). The higher up we are on the chain, the more levels of derivation we've gone through to arrive at that thing. We see this, for instance, in the relationship between a group of individuals, the species they belong to, and the genus they belong to. On the Aristotelian view, we strip away certain properties to arrive at the species to which a group of individuals belong. We repeat the process to arrive at the genus to which those individuals belong. At every level of abstraction, more individuals fall under the same predicate or universal.

In *Metaphysics* Z Aristotle talks about how that which is more primary is more real than the non-primary (1028a10–26); that "'is' is predicable of things, not however in the same sense, but of one sort of thing primarily and of others in a secondary way" (1030a20–25); that, for any two things (including substances: see 1031b3), one might be prior to the other, in which case the latter is posterior to the former. Schaffer corroborates this list: we can say that a fundamental entity is one that is "a prior, primary, independent, ground entity" while a derivative entity is one that is "a posterior, secondary, dependent, grounded entity" (373). On Schaffer's view, "fundamental entity" and "derivative entity" are defined in terms of grounding. Grounding is what gives us the ontological order of entities.

What is important here is that, while some things are derived via abstraction, those things are not, therefore, abstract entities—at least in the way "abstract" is normally used. The typical way to think of abstract entities is, more or less, Platonist. On this kind of view, abstract entities exist necessarily and, when employed in a philosophical theory, are talked about as corresponding to something in the world. For instance, if one uses such entities to construct possible worlds to give a theory of modality, the actual world is the abstract entity that correctly represents our concrete world. On a Platonist view, the abstract entities may be just as fundamental as substances. I'm going to set aside the terms "abstract entity" and "abstract object" to refer to these kinds of Platonic things. But whenever I call something an abstraction, I mean that it is a derived entity.[2]

The view of abstraction that I'll now offer is inspired by Aristotle's metaphysic, and for that reason I will call it an Aristotelian view of abstraction. One motivation for endorsing such a view is that it allows us to do without abstract entities.[3] An Aristotelian view of abstraction, along with the hierarchical ontology discussed above, gives us an alternative to Platonic Forms—and we get the alternative at no ontological cost. Of particular interest are propositions. I will not talk about propositions explicitly, but there is hope that the following allows us to derive propositions. Propositions are an extremely useful tool; to count them among the ontologically innocent would be a boon for the view. Yet my view does not stand or fall on this matter: because propositions are so useful, any serious competitor to my view will need them as well. So, if propositions are not abstractions, then at worst my view is on par with rivals with respect to propositions.

---

[2] Schaffer says that the grounding relations are to be seen as "relations of abstraction," which is to say that "the grounding relations should just be ways of separating out aspects that are implicitly present from the start" (Schaffer 2009a, 378). Given substance monism, every derived entity must be "separated" from the whole, so it is correct that all grounding relations are relations of abstraction. Given substance pluralism there are some derivative things—groups of people, for instance—that need to be "put together" from several substances. These things can also be called abstractions, even though they are not derived by "stripping away" properties from a whole. For the most part it is clear which relation is at work, so I use "abstraction" to refer to things derived via the relation of abstraction as well as things derived via the relation of construction.

[3] See *Metaphysics* Z.8, esp. 1033b20-1034a8, where Aristotle argues that we do not need abstract entities to account for the form that things have.

3.1.1 Abstraction

The process of abstraction involves "removing" (or disregarding) at least some properties or powers from an entity; it is through this process that we derive abstractions. Scaltsas (1994) puts it thus: "for Aristotle a substance is complex, not because it is a conglomeration of distinct abstract components like matter, form, or properties; a substance is complex because such items can be separated out by abstraction, which is a kind of division of the unified substance." Tim Maudlin, in discussing the stripping argument of *Metaphysics* Z.3, talks about abstraction as a stripping process that is "a matter of logical abstraction, or disregarding propeties" (Maudlin 1990, 535). Yet another gloss on this view of abstraction comes from Schaffer: we derive an abstract entity by "separating out aspects that are implicitly present from the start" (Schaffer 2009a, 375). For instance, my character is an abstraction from me. If we "remove" certain things from me, such as some of my causal powers and some other physical properties that I have, we are left with my character. Thus my character is a derivative entity; it is derived from me. While illustrative, these remarks don't do more than offer helpful metaphors about the process of abstraction. I'm going to offer a less metaphorical semantics for abstraction.

But before getting to those semantics, I want to make a brief remark about the nature of abstractions.[4] The above quotes, read in one way, suggest that abstractions depend on the existence of minds. This is not quite right. An abstraction is a part of a substance; as such, whether an abstraction exists does not depend on the existence of minds. Minds are required only for picking out a certain abstraction: the process of abstraction requires a mind because the process involves focusing on a certain part of a substance. There are multiple parts to a substance, and it requires a mind to focus on the right part. I will return to this below, when making discussing how abstractions are of no ontological cost.

[4] Thanks to Todd Buras for making me see the need for this clarification.

One use for abstraction is to put things in categories using kinds.[5] When we categorize, we pay attention only to certain relevant features of things. For example, when we say that something is a wolf, we pay attention only to whether that thing is a vertebrate, has four legs, doesn't have gills, falls within some range for height and weight, and so on; we don't pay attention to the color of the fur or how long the fur is. And if we want to classify some thing as an animal, we pay attention to even fewer traits: we don't look for whether the thing has fur, but we will look to see whether it uses photosynthesis to produce energy and is capable of locomotion. In these cases, abstraction involves forgetting some characteristics of a thing so that we can focus on others.

The examples in the previous paragraph make it clear that there are levels of abstraction, and that these levels are sometimes related. If something is a wolf, then it is an animal, but not conversely. Likewise, if something is a bluebonnet, then it is a plant, but not conversely. This suggests that "animal" denotes a more abstract kind than "wolf", and similarly for "plant" and "bluebonnet". But we need to be careful: even though there's a sense in which "plant" denotes a more abstract kind than does "wolf", it's not because something is a wolf only if it is a plant.

What the previous two paragraphs suggest is that there is an ordering relation on kinds: "x is more abstract than y". The relata of this relation are kinds; so, this relation tells us when one kind is more abstract than another. It is clear that this relation is irreflexive: the kind denoted by "wolf" is not more abstract than itself. The relation is also transitive: the kind denoted by "animal" is more abstract than that denoted by "canine", which is more abstract than the kind denoted by "wolf"; so, the kind denoted by "animal" is more abstract than that denoted by "wolf". We also want the relation to be asymmetric: if the kind denoted by "plant" is more

[5] I say "one use" because there may be more than one kind of abstraction. But I am interested in what is discussed in the passages quoted above: a kind of forgetting so that we can focus on some particular feature of an individual, which we often do in order to categorize.

more abstract than the kind denoted by "cedar tree", then it's not the case that the kind denoted by "cedar tree" is more abstract than the kind denoted by "plant".[6] We should also say whether the relation is total: whether, for any two kinds K_1 and K_2, K_1 is more abstract than K_2 or K_2 is more abstract than K_1. The short answer is that the relation is not total. As we'll see shortly, we can organize kinds according to a level of abstraction, where two kinds that are on the same level are equally abstract. Totality would force us to say that one of these kinds is more abstract than the other.

Biologists say that "timber wolf" and "goldfish" denote species. Among other things, we would say that something is a timber wolf only if it does not have gills, whereas something is a goldfish only if it has gills. Likewise, we would say that something is a timber wolf only if it has four legs and a goldfish only if it does not have four legs.[7] We might think of these characteristics as timber-wolf-insensitive and goldfish-insensitive: two individuals cannot both be timberwolves, if one has gills while the other does not (and likewise for goldfish). And this offers one way to explain why "timber wolf" and "goldfish" each denote species: there are a number of characteristics, such as having gills and having four legs, that we care about when assessing what species something is, and that's the list we use to assess whether something is a timber wolf or a goldfish. We can call characteristics such as having gills and having four legs "species-insensitive" and say that, if two things are the same species, then, for any species-insensitive characteristic, both have or both lack that characteristic. (There are, of course, characteristics that we do not care about—i.e. some characteristics are not species-insensitive—and we ignore whether some thing has or lacks those characteristics when assessing what species the thing is. Think

[6] Asymmetry is guaranteed since the relation is irreflexive and clearly not symmetric. So, even if we adopted anti-symmetry—if a is more abstract than b and b is more abstract than a, then a is identical to b—irreflexivity and anti-symmetry entail asymmetry.

[7] For convenience, I ignore issues related to the characteristics that things *normally* have.

of a panel with a bunch of on/off switches. Imagine that a detector scans an object and then flips the switches to their correct positions. To assess whether two objects are the same species, we need only look at, say, the first ten out of twenty switches; and all we need to check is that the position of those switches stays the same when we scan the two objects. To determine what particular species one of the objects is, we need to look at which of the first ten switches are in the "on" position and which are in the "off" position. We can ignore the position of the other switches.)

We can expand this picture by considering relations similar to "x is the same (biological) species as y": "x is in the same (biological) genus as y", "x is the same cell phone model as y", and "x is the same software version as y", for instance. We can call these relations "leveling-relations" because they pick out a level of abstraction. Leveling-relations assert that two things are the same, relative to that level. These relations will always be transitive and symmetric, but are not, as a rule, reflexive: though some particular iPhone is the same cell phone model as itself, it is not the same (biological) species as itself.[8] And whether two kinds are on the same level is a matter of whether we use, for each kind, the same collection of insensitive predicates to determine whether something is a member of the kind: kinds K_1 and K_2 are on the same level iff, for any predicate F, F is K_1-insensitive iff F is K_2-insensitive.[9]

We can build on the idea of a leveling-relation as follows. I will use "$\mathcal{K}$" as a variable for leveling relations. (Since "$\mathcal{K}$" is a variable for a relation, "$\mathcal{K}(x, y)$" is not

[8] In case this sounds puzzling, note that a symmetric and transitive relation R will not be reflexive unless it is also serial: for every x there is some y such that $R(x, y)$. Since it is not true that, for any iPhone there is some y such that the iPhone and y are the same species, we avoid the consequence that an iPhone is the same (biological) species as itself.

[9] If we use the exact same list insensitive predicates to assess which of two kinds something is, those kinds should be equally abstract. And this gives a slightly more detailed explanation for why "is more abstract than" should not be total.

itself a relation; but you may read it as "x is the same kind as y" for convenience.) We can then define what I will call a "$\mathcal{K}$-insensitive predicate":

Unary $\mathcal{K}$-insensitivity: A unary predicate F is $\mathcal{K}$-insensitive iff, for any x and y, if $\mathcal{K}(x, y)$, then $F(x)$ iff $F(y)$.

We've already seen one instance of this: A unary predicate F is species-insensitive iff, for any x and y, if x is the same species as y, then $F(x)$ iff $F(y)$. In what follows I usually restrict myself to unary predicates for simplicity; but for the sake of completeness, I will offer definitions for $\mathcal{K}$-insensitivity with respect to a given argument for predicates of higher arity. For instance:

Binary $\mathcal{K}$-insensitivity 1: A binary predicate F is $\mathcal{K}$-insensitive with respect to the first argument iff, for any x and y, if $\mathcal{K}(x, y)$, then, for any z, $F(x, z)$ iff $F(y, z)$.

Binary $\mathcal{K}$-insensitivity 2: A binary predicate F is $\mathcal{K}$-insensitive with respect to the second argument iff, for any x and y, if $\mathcal{K}(x, y)$, then, for any z, $F(z, x)$ iff $F(z, y)$.

We can, of course, generalize this for predicates of arbitrary arity:

$\mathcal{K}$-insensitivity: $F(u_1, \ldots, u_k)$ is $\mathcal{K}$-insensitive with respect to the i^{th} argument iff for any x, y, u_1, $\ldots$, u_k, if $\mathcal{K}(x, y)$, then $F(u_1, \ldots, u_{i-1}, x, u_{i+1}, \ldots, u_k)$ iff $F(u_1, \ldots, u_{i-1}, y, u_{i+1}, \ldots, u_k)$.

We can also use the $\mathcal{K}$ relations to define identity relative to a kind:

$\mathcal{K}$-identity: $I_{\mathcal{K}}(x, y)$ iff $\mathcal{K}(x, y)$.

When $\mathcal{K}$ is the conspecificity relation, the relevant instance of $\mathcal{K}$-identity would read "x is species-identical to y iff x is the same species as y". $\mathcal{K}$-identity tells us that any two things that are the same kind are, relative to that kind, one and the same. One way to justify this is that, when we are talking about some species that exists, it doesn't matter which member of a species we are referring to; because we pay attention only to $\mathcal{K}$-insensitive predicates, it doesn't matter which individual we choose since they are all the same relative to that kind. (Going back to the panel of on/off switches: if the two objects are the same species, then the relevant switches stay in the same position. So, we could talk about that species without knowing which specific object we are referring to. And in a certain sense, it doesn't matter since we are concentrating only on the position of the relevant switches, not the object as a whole.)

And now we can show how this view of abstraction offers a way to talk about things like mammoths and magnolias without requiring Platonic entities. To do that, I will introduce some new quantifiers, which I will call "$\mathcal{K}$-quantifiers". I will then offer two examples to show that abstraction affords us a way to talk about kinds without Platonic entities.

$\mathcal{K}$-quantifiers have the same syntax as the quantifiers in ordinary FOL with one additional rule: any variable bound by a $\mathcal{K}$-quantifier can appear only in $\mathcal{K}$-insensitive places in a predicate. I will denote these new quantifiers with "$\forall_{\mathcal{K}}$" and "$\exists_{\mathcal{K}}$", where "$\mathcal{K}$" is, as above, a variable for a leveling relation. If we are considering the conspecificity relation, the $\mathcal{K}$-universal quantifier would be read as "Any member of a species ..." or "Every member of a species ...", while the $\mathcal{K}$-existential quantifier would read "There is some members of a species ...". The semantics for $\mathcal{K}$-quantifiers are simple, and even afford a way of translating from sentences with $\mathcal{K}$-quantifiers to sentences with only ordinary FOL quantifiers. Where "$\mathcal{F}$" is a variable for any well-formed formula, we have:

$\mathcal{K}$-universal: $\forall_{\mathcal{K}} x\mathcal{F}(x)$ iff $\forall x(\mathcal{K}(x,x) \rightarrow \mathcal{F}(x))$;

$\mathcal{K}$-existential: $\exists_{\mathcal{K}} x\mathcal{F}(x)$ iff $\exists x(\mathcal{K}(x,x) \wedge \mathcal{F}(x))$.

A convenient way to read the left-hand side of each biconditional, when we're considering the conspecificity relation, is "Every member of a species is $\mathcal{F}$" (more colloquially: "every species is $\mathcal{F}$") and "Some member of a species is $\mathcal{F}$" ("some species is $\mathcal{F}$"), respectively. Note that there is no stipulation that $\mathcal{F}$ is $\mathcal{K}$-insensitive.

The reason for this is specific to each quantifier. For the $\mathcal{K}$-universal quantifier, "$\forall x(\mathcal{K}(x,x) \rightarrow \mathcal{F}(x))$" implies that $\mathcal{F}$ is $\mathcal{K}$-insensitive.[10] For the $\mathcal{K}$-existential quantifier, the obvious way to stipulate that $\mathcal{F}$ is $\mathcal{K}$-insensitive is to change the semantics to:

$\mathcal{K}$-existential*: $\exists_{\mathcal{K}} x \mathcal{F}(x)$ iff $\exists x(\mathcal{K}(x,x) \wedge (\mathcal{F}(x) \wedge \mathcal{F}$ is $\mathcal{K}$-insensitive$))$.

Consider the predicate "is a woman". This predicate is not species-insensitive; so, according to $\mathcal{K}$-existential*, it's not true that some member of a species is a woman—but that's clearly false!

$\mathcal{K}$-quantified sentences, specifically sentences in which the $\mathcal{K}$-existential quantifier takes wide scope, allow us to talk about all kinds of things without requiring an increase in our ontology. Consider the sentence "Some species have legs". This sentence is true. One naïve, Platonist interpretation of this sentence is that there is some (abstract) thing, a species, that has legs. This is a weird interpretation: species are not the sorts of things that have legs—individuals are the sorts of things that have legs! A slightly better Platonist interpretation might say that there are two abstract entities, speciesness and leggedness, and some fundamental entity instantiates (or participates in) both abstract entities. But we can do without these entities. Suppose the ordinary FOL quantifiers have only fundamental entities in their domain (which is an attractive view for the Aristotelian). Letting "$S(x,y)$" mean "x is the same species as y" and "$L(x)$" mean "x has legs", we can express "Some species have legs" as "$\exists_S x L(x)$", which is true if and only if there is some (fundamental) entity x such that x is the same species as itself (i.e. x is a member of a species) and x has legs. Since there is a fundamental thing that is the same

[10] Here's a sketch of the proof. Let K be a leveling-relation and F be some predicate. Suppose, for reductio, that $\forall x(K(x,x) \rightarrow F(x))$ but it's not the case that $\forall x \forall y(K(x,y) \rightarrow (F(x) \leftrightarrow F(y)))$. Then let a and b be individuals such that $K(a,b) \wedge \neg(Fa \leftrightarrow Fb)$. We also have $K(a,a) \rightarrow Fa$ and $K(b,b) \rightarrow Fb$. Since K is transitive and symmetric, from $K(a,b)$ we can infer both $K(a,a)$ and $K(b,b)$. Given $K(a,a) \rightarrow Fa$ and $K(b,b) \rightarrow Fb$, it then follows that Fa and Fb. But $Fa \wedge Fb$ imples $Fa \leftrightarrow Fb$, which contradicts $\neg(Fa \leftrightarrow Fb)$. So, "$\forall x(K(x,x) \rightarrow F(x))$" implies "$\forall x \forall y(K(x,y) \rightarrow (F(x) \leftrightarrow F(y)))$".

species as itself and that thing has legs, it's true that some species have legs. We don't need abstract entities to account for the truth of the claim that some species have legs. And this will hold for similar claims as well: statements about cell phone models, software versions, etc.[11]

For a second example, consider the sentence "There are black bears". One way to explain the truth of this sentence is to say that some thing instantiates (or participates in) some abstract entity, black-bear-ness. In other words, there is some x such that x is a black bear because x instantiates (or participates in) the abstract entity black-bear-ness. But the Aristotelian can do without this abstract entity. "Black bear" denotes a species. As discussed above, what distinguishes black bears from goldfish is which of the species-insensitive predicates must be true of an individual in order for that individual to be a member of that species. For instance, an entity cannot be a black bear unless it lacks gills and has four legs; whereas an entity cannot be a goldfish unless it has gills yet lacks four legs. We can then say that "There are black bears" is shorthand for "There is some species that lacks gills, has four legs, ...", where "..." is filled out by the remaining species-insensitive predicates. Paraphrasing "There are black bears" this way makes it clear that we do not need abstract entities: all of the explanatory work is done by the fundamental (non-abstract) entity. And we can generalize this not only for other terms that denote species, but also for any term that denotes a kind that is the relata of some leveling relation: any such term is shorthand for a conjunction of $\mathcal{K}$-insensitive predicates. Taking this a step further, we could say that a kind just is a

[11] Though in each of these cases, we may need to tweak the semantics. Consider "Some cell phone models have touch screens". Let "$M(x, y)$" mean "x is the same cell phone model as y" and "$T(x)$" means "x has a touch screen". Then "$\exists_M x T(x)$" is true iff there's some (fundamental) entity that is the same cell phone model as itself, that thing has a touch screen, and $M(x)$ is cell-phone-model insensitive. But if fundamental entities are the only objects in the domain of the ordinary FOL quantifiers and, as is plausible, if cell phones are derivative entities, the semantics won't work, as stated. I don't intend to explore this issue further, but I suspect that once we have a view of construction worked out, we can employ that to expand the semantics for $\mathcal{K}$-quantifiers to deal with such cases.

conjunction of $\mathcal{K}$-insensitive predicates. This advantageous for two reasons. First, it means that we can talk about kinds that don't exist: as long as we can articulate the right conjunction of $\mathcal{K}$-insensitive predicates, we can talk about that kind. Second, it further supports the claim that two things that are the same species, e.g., are one and the same relative to that level of abstraction: if we're only concerned about a conjunction of predicates, it doesn't really matter which particular individual we are referring to.

Saying that an abstraction just is a conjunction of $\mathcal{K}$-insensitive predicates allows us to clarify the above remarks about the nature of abstractions. At the beginning of this section I noted that an abstraction does not require a mind to exist. If abstractions just are a certain kind of conjunction, it is clear why that is the case: whether a substance has certain properties does not depend on the existence of minds. Minds come into play only when picking out certain properties and giving them names. Mereological universalism is an analogous and helpful case to consider. Mereological universalists maintain that, for any number of objects (the xs), there is yet another object that is composed of the xs. It is clear that this view entails the existence of many objects; moreover, the existence of these objects does not depend on the existence of minds. Nonetheless, minds are required for picking out certain objects (and ignoring others). Something similar holds for abstractions: there are many abstractions that are a part of any given substance, but it is minds that are responsible for paying attention to some of these parts while ignoring others.

3.1.2 Construction

So far the Aristotelian has abstractions, which are parts of substances. That's a good start, but the Aristotelian's world might still seem a little impoverished. Some things, like groups of people, fictional characters, and (probably all) artifacts, can't be derived just by stripping away properties from substances. Unless groups of people, fictional characters, and artifacts are fundamental entities, they need to be constructed from substances. Karen Bennett (2011) notes that there are many kinds of construction (or building) relations, of which emergence, supervenience, composition, and constitution are but a few.[12] To discuss construction relations in significant detail would go beyond the scope of this paper; but I do want to gesture at one candidate for a construction relation. So, in this section I will suggest (and only suggest) that a modified version of universal mereological composition is a promising candidate for a construction relation.

Universal mereological composition constructs entities by guaranteeing the existence of mereological fusions (or sums):

UMC: For any xs, there exists a y such that y is the fusion of the xs.[13]

How useful UMC is depends on how we interpret the quantifiers. On this matter, there are two desiderata, one for each quantifier. To get a truly universal construction principle, we would like to use both fundamental and derivative entities to construct further derivative entities. Consequently, we would like the universal quantifier in UMC to range over both fundamental and derivative entities. To avoid an objectionable increase in the number of fundamental entities, we would like the existential quantifier to be something other than the ordinary existential quantifier, since its domain consists of fundamental entities. The following proposals are suggestions for how to meet these desiderata.

As of yet, we do not have quantifiers that encompasses both fundamental and derivative entities. But it is easy to define them:

Max-$\forall$: $\forall_M x\mathcal{F}(x)$ iff $\forall x\mathcal{F}(x)$ and, for every $\mathcal{K}$, $\forall_{\mathcal{K}} x\mathcal{F}(x)$ (i.e. iff everything, whether fundamental or derivative, is $\mathcal{F}$);

---

[12] Kit Fine (1991) offers some requirements for a constructional ontology; (Fine 2010) and (Wilsch 2015) offer different views on construction.

[13] I take this formulation of UMC from (Hudson 2006).

Max-∃: $\exists_M x\mathcal{F}(x)$ iff $\exists x\mathcal{F}(x)$ or, for some $\mathcal{K}$, $\exists_{\mathcal{K}} x\mathcal{F}(x)$ (i.e. iff something, whether fundamental or derivative, is $\mathcal{F}$).

The "for every $\mathcal{K}$" and "for some $\mathcal{K}$" are not intended to be read as objectual quantification over predicates (for that would seem to require a commitment to abstracta as fundamental entities, which the Aristotelian is trying to avoid). Instead, "for every $\mathcal{K}$" and "for some $\mathcal{K}$" are intended to be read as substitutional quantification over predicates. The difference between the two kinds of quantification is that objectual quantification "appeals to the *values* of the variables", while substitutional quantification "appeals, not to the values, but to the *substituends* for the variables, the expressions, that is, that can be substituted for the variables" (Haack 1978, 42). So, "for every $\mathcal{K}$, $\forall_{\mathcal{K}} x\mathcal{F}(x)$" ends up being shorthand for a (long) conjunction, one which has a conjunct for every predicate—and analogously for "for some $\mathcal{K}$, $\forall_{\mathcal{K}} x\mathcal{F}(x)$". Of course, whether you find this proposal viable depends on what you make of substitutional quantification—and there certainly are critics of this kind of quantification.[14]

We would also like to change the existential quantifier in UMC so that fusions have no ontological cost. To do this, one might try to use the $\mathcal{K}$-existential quantifier defined above, since entities in the domain of a $\mathcal{K}$-existential quantifier have no ontological cost. Combining this idea with the previous proposal, we could then modify UMC to get:

UMC*: For any$_M$ xs, there exists$_{\mathcal{K}}$ a y such that y is the fusion of the xs.

If you are an ontological pluralist, this principle will get you into some trouble. For recall that $\exists_{\mathcal{K}} x\mathcal{F}(x)$ is true iff there is some fundamental entity that is $\mathcal{F}$. This suggests that, at the end of the day, there needs to be some fundamental entity that is the fusion of the xs. Since the purpose of invoking $\mathcal{K}$-quantifiers is to reduce ontological cost, it would be embarrassing if we ended up having to increase our

[14] See, for instance, (Lycan 1979) and (Inwagen 1981).

fundamental ontology to construct derivative entities. In light of this, the pluralist might try to define another quantifier, one which allows us to say what a fusion is in terms that don't imply that fusions are fundamental entities. A consequence of this move is that ontological pluralists need two kinds of grounding relations (one for abstracting, or breaking things apart, and one for constructing, or putting things together)—which in the present framework is expressed by two distinct kinds of quantifiers which range over distinct (and most likely disjoint) collections of non-fundamental entities. This is an interesting result because it connects ontological pluralism to grounding pluralism.[15] Furthermore, this position is in opposition to the common thought that there is a univocal notion of grounding.[16] But the aim of this section was to develop a view of abstraction, so I am not concerned to pursue this discussion any further.

3.2 Substantivity

While I've shown that my taxonomy has a place for every possible view of time, it is possible to question whether it is the best (or even a good) way to carve up logical space. One way to defend the claim that the taxonomy is a good way to carve up logical space is to show that the theses it uses to partition logical space are substantive.[17] I take the term "substantive" from Sider (2011) and here discuss what substantivity is from within the Aristotelian framework laid out above.

Sider's view of substantivity is stated in terms of expressions that carve nature at the joints. A term carves at the joints when it gets at nature's fundamental structure, where "structure" is a technical and primitive term for Sider. While it

---

[15] The ontological monist, by contrast, need not invoke another quantifier since all derivative entities will be abstractions from the one fundamental entity.

[16] See, for instance, (Correia 2005), (Fine 2012), (Rosen 2010), (Schaffer 2009a), and (Trogdon 2013).

[17] Equivalently: debating the truth of any of those theses is not a merely verbal dispute.

is expressions that carve at the joints (or fail to do so), it is sentences that are substantive (or not). If we think of a question as "a set of sentences that are its possible answers" we can say that

> for one or more expressions E (e.g. "bachelor") in a nonsubstantive question, the semantic candidates for E (unmarried adult-male, unmarried-adult-male-eligible-for-marriage, etc.) are such that i) each opposing view about the question comes out true on some candidate; and ii) no candidate carves at the joints better than the other (Sider 2011, 46–47).

Given this characterization of nonsubstantivity, Sider goes on to say that a substantive question "is one that is not nonsubstantive" (46). Sentences may be nonsubstantive as well: "a sentence is nonsubstantive iff the candidates of some expression are equistructural and both the sentence and its negation come out true under some candidate" (48). Lest this seem like there is a candidate under which a sentence is both true and false, we should clarify what Sider means: there is some candidate under which the sentence comes out true and another (hopefully distinct candidate!) under which the sentence is false. He notes that being cast in joint-carving terms is not "the sole determiner of substantivity" but is normally sufficient, though not necessary (47). He offers several refinements of his view, but these preliminaries are enough to give the general framework that I will adopt.

A related view is offered by Chalmers (2011). Like Sider, Chalmers proposes that a dispute over some sentence S is a verbal dispute "when for some expression T in S, the parties disagree about the meaning of T, and the dispute over S arises wholly in virtue of this disagreement regarding T" (522). Chalmers notes that this view of verbal disputes leads to a kind of deflationism about questions of the form "What is X?". He goes on to say that instead of focusing on the question of what X is,

> one should focus on the roles one wants X to play, and see what can play that role. The roles in question here may in principle be properties of all sorts: so one focuses on the properties one wants

> X to have and figures out what has those properties. But very frequently, they will be causal roles, normative roles, and especially explanatory roles. (Chalmers 2011, 538)

That is, a debate can ask two kinds of questions: "What is X?" and "Does X have property F?"; the latter is the one that we should focus on when we have a merely verbal dispute (i.e. a nonsubstantive question).[18]

I'm going to adapt these models of substantivity for the Aristotelian framework described above. I'm going to put Sider's view of substantivity in terms that the Aristotelian will be happy with and then suggest that Chalmers has the right idea for how to proceed when faced with a non-substantive debate.

The Aristotelian is concerned with what entities are fundamental and how to derive non-fundamental entities. Above we saw that we can give a semantics for derivation by appealing to certain kinds of predicates. A first pass at adapting Sider's view of substantivity to an Aristotelian framework, then, we need to swap out talk about equistructural expressions and replace it with talk about fundamentality. The Aristotelian can say the following about substantivity with respect to sentences and questions:

Sentences: A sentence S is *nonsubstantive* iff the candidates for some expression E are all equally fundamental and under one candidate for the E, S comes out true while under another candidate for E, $\neg S$ comes out true.

[18] There is a distinction that is worth mentioning but not spending much time on. In the text, "X" is most naturally taken as a variable for entities. But we might want to talk about substantivity with respect to theories: "What is T?", or "Is T true?" This points out nicely how a dispute can be merely verbal. The question "What is evolution?" is a nonsubstantive one. There are multiple candidates for evolution—punctuated equilibrium theory and gradualism, for instance—that could be called "evolution". Which of those we call "evolution" does not seem to matter much; what we care about is whether one of the views is true. If we view theories as conjunctions of propositions, this means that the main concern is whether a certain conjunction is true, just as the main concern for a verbal dispute regarding an entity is whether we have the right roles getting filled.

Questions: A question is *nonsubstantive* iff the candidates for some expression are all equally fundamental and each answer comes out true under some candidate.

Before saying more about nonsubstantivity, it will be helpful to go through a few examples. The aim of these is not to show that the Aristotelian is committed to holding that these debates are nonsubstantive; the aim is simply illustrative. To actually support the conclusions drawn requires a bit more work than I intend to do here.

First nonsubstantive question: Pointing to an arrangement of colored fur on a tiger, one can ask "Is that a stripe?" This question is nonsubstantive because stripes are derivative entities; a stripe is an abstraction from a substance. Much like "bald", "stripe" is also vague: some arrangements of colored fur clearly are stripes, others are not, and sometimes there's no definite answer. This kind of indeterminacy shows that there are multiple candidate entities that can be the value of a variable for the predicate "is a stripe", i.e. that can play the role of a stripe. Which one we use as our paradigm as a stripe will (mostly) determine how many arrangements of colored fur we count as stripes, which, in turn, affects our answer to the question.

Note that this explanation relies on an imaginative view of abstraction: the abstractions are things we imagine in our mind. Not every abstraction is something that is imagined, but cases in which we do imagine the abstraction are particularly helpful for seeing when a debate is nonsubstantive, for imaginings tend to leave several determinables undetermined.[19] For instance, when I imagine a tiger, the number of stripes is, often, indeterminate. And it is when we ask questions about undetermined determinables that we arrive at a nonsubstantive debate.

Second nonsubstantive question: Are propositions structured? "Proposition" is a theoretical term; as such, it plays a role (or perhaps more than one) in our

[19] Cf. (Kung 2010)

theories. For the Aristotelian, propositions are not substances; thus they are derived entities. Given this, it would be surprising if it were impossible for the Aristotelian to be able to abstract two kinds of entities, one structured and the other not, both of which played all the roles that propositions are supposed to play. But if either entity can fill all the roles of propositions, and neither is more fundamental than the other, then the question is nonsubstantive (and propositions have no ontological cost).

Third nonsubstantive question: Is 2 the set $\{\varnothing, \{\varnothing\}\}$?[20] The natural numbers can be derived from sets. But, as Benacerraf (1965) showed, there are multiple candidates for the numbers. Even if we agree that 1 is the set $\{\varnothing\}$, we have (at least) two options for 2: $\{\varnothing, \{\varnothing\}\}$ or $\{\{\varnothing\}\}$. Both of these are sufficiently suited to play the (mathematical) role that 2 has; thus the debate is nonsubstantive.

Fourth nonsubstantive question: Did the game last 90 minutes? This example is closer to what will be discussed later on and draws an important distinction between substantivity and objectivity.[21] In general, how long an event lasts is objective but nonsubstantive. The debate is objective because, once we've fixed a unit of measure, there is an answer to the question (barring vagueness about when an event began and ended). The debate is nonsubstantive because it depends on fixing a unit of measure. Fixing a unit of measure gives rise to nonsubstantivity. Sider puts the point nicely:

> consider the word "inch". The purpose of "inch" is to be a convenient measure for smallish things, the kinds of things we can hold in our hands. But there is a range of very similar lengths that would each have served this purpose. We chose one of these to mean by "inch", but that choice was arbitrary; any of the others would have served our purposes equally well. This choice was one of candidate-selection convention. (Sider 2011, 54)

[20] Here I am going to assume that sets are more fundamental than numbers are; this assumption further highlights that I do not intend these examples to be anything more than examples.

[21] Cf. (Sider 2011, S4.3).

Whenever we have such conventionality, questions in which these terms appear are nonsubstantive.[22] In terms of entities, the Aristotelian will say that a unit of measurement is abstracted from some natural process (for units of temporal measurement) or from some object (for units of spatial measurement). There are several natural processes that could serve as the ground for a smallish amount of time, any of which would play the role of a minute equally well; thus the debate is nonsubstantive.[23]

Chalmers claims that adopting a view of nonsubstantivity like the one he suggests (which is a more general version of the view just presented) leads to deflationism about questions of the form "What is X?". Given this, we should then adopt a functionalist attitude towards X: see what roles X plays and then look for things that play those roles. It turns out that the Aristotelian can offering some edifying remarks about this attitude. For nonsubstantive sentences and questions, the candidates for the value of a variable in a $\mathcal{K}$-insensitive predicate all have some properties in common.[24] We can think of the roles that X plays as the properties that all of the candidates have in common. Turned around, we have a justification for a functionalist attitude towards certain kinds of things: roles do not always determine a unique entity to play that role, which leads to indeterminacy about what X is; and it is that indeterminacy that gives rise to nonsubstantivity.[25] In fact, this seems to

---

[22] What is indicative of candidate-selection conventionality is that we choose one candidate meaning for the sake of accomplishing some semantic goal (Sider 2011, 54). All terms of length are like this. See also (Skow 2010).

[23] This does not mean that there is no reason for choosing one process over another. As we will see later on, considerations of simplicity in scientific theories often push us to choose one process as the unit of measurement over the other. Nonetheless, *that* several other candidates are available is what makes the question nonsubstantive.

[24] To say that some entities have some properties in common is a shorter way of saying that there are some other $\mathcal{K}$-insensitive predicates for which those entities are values for a variable in that predicate.

[25] Cf. (Sidelle 2007)

be favorable evidence for a functionalist attitude about all non-fundamental entities. If a debate is nonsubstantive because all of the equally fundamental candidates are non-fundamental things, that suggests that what really matters in the debate is not what the thing is but rather what roles the thing is supposed to play.

A functionalist attitude towards non-fundamental entities has a direct effect on one kind of question regarding comparative fundamentality: Is X derived from Y? If X and Y are not fundamental entities, then whether this question is substantive depends on what candidates are available to play the roles of X and Y. Suppose there are two candidates for X, x_1 and x_2, and two candidates for Y, y_1 and y_2. Further, assume that x_1 is derived from y_1 but y_2 is derived from x_2. Given the first pair of candidates, X is derived from Y; given the second, X is not derived from Y. This does not yet yield nonsubstantivity because we need to consider whether the candidates are equally fundamental. And here we need to be careful. If there are discrete levels of fundamentality, we don't want to say that x_1 and x_2 must be on the same level and that the same must be true of y_1 and y_2—that violates the set up for the case.[26] There are probably other approaches once could pursue, but the simplest is to take a liberal reading of "equally fundamental": two entities are equally fundamental provided that (i) both are fundamental or both are not fundamental, and (ii) if both are not fundamental, then one is not derived (in whole or in part) from the other. On this reading, whether the question is substantive hinges on whether y_1 and x_2 satisfy (ii). As we'll see below, there are questions about time that are like this and are nonsubstantive.

The substantive debates, then, are (mostly) those that are about substances, the fundamental entities, and (sometimes) what is derived from what. Given the view of time that I will champion, this entails the nonsubstantivity of several ques-

[26] There is also a worry about what to make of discrete levels of fundamentality; cf. the remark on Leibniz in chapter two.

tions in the philosophy of time. This does not mean that those debates are not important, however. While some debates are non-substantive, they might still be important or have objective an answer: nonsubstantivity *does not* entail unimportance or subjectivity.[27] The reason is that the substantivity in question here is a metaphysical variety. Conceptual substantivity is a different animal, and it is possible for a debate to be metaphysically nonsubstantive while conceptually substantive. In such a case, it seems that a question can still be important. One reason for this is that debates about the nature of abstractions indirectly informs us about the fundamental entities, since abstractions are derived from the fundamental ones. So, provided that we are paying attention to the way in which we carry out the abstraction process, some questions about derived entities can prove quite fruitful.[28]

3.3 Space and Time vs. Spacetime

The debate between substantivalists and relationalists was originally a debate with respect to space and time. Contemporary physics no longer sees space and time as two separate things, but rather as one thing: spacetime. This change complicates matters because spacetime in the general theory of relativity is not just a combination of space and time, so there is no guarantee that the morals we draw about space and time will apply to spacetime. So, it is a live question whether the distinction between space and time, and spacetime, really matters. In this section I will first discuss the differences between the two ways of talking about the world. I will then argue that the question of whether the distinction matters is not necessarily substantive: it is substantive iff substantivalism is true. This is a boon for the

[27] Following Sider the converse seems true as well: not every debate about fundamental entities is important.

[28] In fact, this seems to be an explanation of why regression analysis is so useful: we learn something about people, for instance, by ignoring certain properties that some of them have.

relationalist, for it affords the relationalist a degree of flexibility in explicating and defending relationalism that the substantivalist does not have.

3.3.1 The Transition from Space and Time to Spacetime

The advent of relativity theory brought with it a significant conceptual change. Newtonian physics viewed space and time as two distinct entities. Relativity theory did away with this distinction and instead talked about spacetime. Rather than speaking of a three-dimensional spatial manifold with a one-dimensional temporal one, relativity theory speaks only of a four-dimensional spacetime manifold. The aim of this section is to show that this conceptual change need not raise a substantive ontological debate.

The first significant change in this transition is the way that locations are talked about. If space and time are separate, we talk about points in space and points in time. Spacetime theories do not talk of points; instead they talk of events. In spacetime theories "event" gets used differently than it does in most philosophical contexts. Rather than risk ambiguity, I am going to use "manifold event" to refer to the events of a spacetime theory; "event" will keep its usual meaning. Manifold events are the "basic building blocks" of a spacetime theory (Geroch 1978, 3). Manifold events are similar to what a mathematician means by "point of a manifold". I will say more about manifold events below; for now it is enough to note that the change from theories of space and time to theories of spacetime brought with it a change in how we talk about locations.

The second significant change from the transition is the loss of a relation of absolute simultaneity. If space and time are distinct, it is easy to make sense of a relation of absolute simultaneity because we have a distinct temporal order. Formally, this is accomplished by taking equivalence classes on the space $E^3 \times T$, where E^3 represents three-dimensional Euclidean space and T represents the one-dimensional temporal order. Spacetime, on the other hand, starts with a four-dimensional manifold of manifold events. We can define a simultaneity relation in the same way we did with space and time. However, simultaneity is always relative to a frame of reference; there is no absolute (or privileged) frame of reference. One reason for thinking this is that starting with a timeline gives a reason for privileging the class of reference frames based on that timeline. For spacetime, we have no such reason to privilege one class of reference frames over another.

The second change has, by far, been given more attention in the literature than the first. Most think that the loss of a physical basis for absolute simultaneity has ontological implications. For one, it seems to be the death knell for substantivalism about space and time.[29] As Bardon puts the point:

> If simultaneity is relative, then there is no absolute time. No one can say when a given event occurs, or what time it is now, with an authority that transcends one's frame of reference. *What time it is 'now' depends on one's inertial frame of reference.* (Bardon 2013, 65, his emphasis)

If this is correct, then the only prospect for holding substantivalism about space and time is to offer a metaphysical basis for a relation of absolute simultaneity. Indeed Michael Tooley (1997) gives an in-depth reconstruction of relativity theory with an absolute simultaneity relation, one which has no observable consequences. William Lane Craig (2000, ch. 4–5) makes a similar claim: we can have a metaphysical absolute simultaneity relation even if the physical theory does not have a physical absolute simultaneity relation.

A second alleged consequence of the loss of absolute simultaneity is that presentism is false. Presentism is the view that the only things that exist are those that exist now. According to presentists, dinosaurs and future Martian outposts do not exist. But presentism seems to require a relation of absolute simultaneity. Relativity

---

[29] See, for instance, (Bardon 2013) and (Rovelli 2006).

theory has the resources to say that some things are absolutely past and others are absolutely future from some point of spacetime, but that is not good enough for the presentist. For, the argument goes, there are still events that are future relative to one reference frame but present relative to another. But this lands the presentist in a contradiction, for it means that future events exists, something the presentist expressly denies.[30] Further, it seems unattractive to claim that existence is vague or not absolute. Among the responses available to the presentist are those mentioned in the previous paragraph: defend, on metaphysical grounds, a relation of absolute simultaneity.

Carlo Rovelli takes a different interpretation of the advent of general relativity. While most focus on the loss of absolute simultaneity, Rovelli notes that general relativity takes us back to the pre-Newtonian, Aristotelian/Cartesian view of space and time. He starts by noting that "Einstein's discovery is that Newtonian space and time and the gravitational field are the same entity" (Rovelli 2006, 27). He goes on to say that

> The clean way of expressing Einstein's discovery is to say that there are no space and time: there are only dynamical objects. The world is made by dynamical fields. These do not live in, or on, spacetime: they form and exhaust reality. (27)

Rovelli defends this claim on two fronts. First, since there is no privileged distinction between space and time in relativistic spacetime, one cannot hold substantivalism about both space and time. Second, we shouldn't say that spacetime is an entity like Newtonian space and time. Relativistic spacetime is often identified with the gravitational field. But we only identify spacetime with the gravitational field for

---

[30] I don't think this argument is all that persuasive. The argument is successful against the presentist only if the existence of manifold events entails the existence of events. While the existence of events will guarantee the existence of manifold events, there is no reason to think that the presentist cannot get manifold events some other way. (Hence why I included the "so the argument goes".) It seems that arguments like this often do not distinguish events from manifold events; that, or they require assumptions about the relationship between events and manifold events that you don't get for free.

convenience—"we live in a portion of the universe where the gravitational field is sufficiently constant for us to use it as a convenient reference" (Rovelli 2006, 27). Had we inhabited a different part of the universe, it may have been more convenient to use the electromagnetic field as a fixed background. If Rovelli is right about this, we are left with two options. First, if there are multiple fields that make up the world, and none is identical to spacetime, there is no such thing as spacetime.[31] Second, there is such a thing as spacetime, and it could be any one of the dynamical fields; i.e. "spacetime" has multiple candidate referents.

3.3.2 Defining Space, Time, and Spacetime

Below I will raise the issue of whether the transition from space and time to spacetime really matters. That is, I will consider whether the change is merely one of terminology and thus does not underly a significant ontological change. Before discussing that, it will be helpful to say more about the manifolds that are discussed.

Introductions to spacetime theories introduce relativistic theories by discussing pre-relativistic theories and talking about those theories in terms of a four-dimensional spacetime manifold.[32] For pre-relativistic theories, we get a four-dimensional spacetime manifold by combining a three-dimensional spatial manifold, $\mathcal{S}$, with a one-dimensional temporal manifold, $\mathcal{T}$. $\mathcal{S} \times \mathcal{T}$ is the four-dimensional spacetime manifold. $\mathcal{S} \times \mathcal{T}$ preserves the structure that space and time have on the pre-relativistic views. For instance, on a Newtonian view absolute space and absolute time have an affine structure; the resulting four-dimensional manifold has this structure as well.

Relativistic theories, on the other hand, do not construct the spacetime manifold from a spatial manifold and a temporal manifold. Instead, relativistic theories start with a four-dimensional manifold, $\mathcal{M}$, of manifold events. This attributes

[31] Option 1.5: you might think that all of the dynamical fields reduce to one single field, and that the single field is spacetime; then you can avoid the first option.

[32] See, for instance, (Sklar 1974), (Geroch 1978), (Bardon 2013), and (Meyer 2013).

less structure to spacetime than does, say, Newtonian spacetime. One can add more structure to the manifold, though. For instance, we can say that relativistic spacetime is a four-dimensional manifold of events with a geodesic structure and a metric.[33]

I've not attempted to define $\mathcal{S}$, $\mathcal{T}$, and $\mathcal{M}$. All I've done is point out that there are two ways to arrive at a four-dimensional spacetime manifold. The first takes space and time as conceptually prior: it is from space and time that we derive spacetime. The second takes spacetime as conceptually prior: insofar as we can separate the manifold into space and time, we can do so only after we have spacetime. In both cases we still have a four-dimensional spacetime manifold. One might wonder whether it matters which way we choose, whether it makes any difference to start with two manifolds or with just one. This is not to ask whether our choice between a pre-relativistic theory and a relativistic one matters. The different ways of arriving at a four-dimensional spacetime are discussed in terms of pre-relativistic and relativistic theories, but that is for illustration. The question that I am asking is whether there is anything more than conceptual priority at stake.[34]

3.3.3 Does the Distinction Matter?

We've seen that one can discuss time or spacetime. It's natural to ask whether the choice matters. Our ordinary way of talking uses temporal vocabulary; contemporary physics uses spatiotemporal vocabulary. As we'll see in the next chapter, any adequate view of time must be in accord with our best physical theories and with parts of the folk theory of time. So it looks like a view of time will need both

---

[33] This is what (Sklar 1974, 62) recommends for the spacetime substantivalist. Norton (2014) recommends that the spacetime substantivalist stick with the claim that spacetime is just the manifold.

[34] Not that conceptual priority is not important: starting with two manifolds and deriving a third may predispose one to think that there is a privileged frame of reference. Nonetheless, if the question of derivation is nonsubstantive, then it is conceptual priority alone that is at stake.

time and spacetime in its ontology. Given the Aristotelian view of abstraction, this is not much of a burden since any adequate view of time gets at least one of time and spacetime for free. This raises a question: Is the question "Is spacetime more fundamental than space and time?" substantive? I am going to argue that the question is substantive iff substantivalism is true.

As we've seen, if substantivalism is false, neither time nor spacetime are fundamental entities, i.e. both are derived. But if both are derived entities, the question of which is derived from the other is non-substantive. As was pointed out above, one can start with both a spatial and temporal manifold and derive the spatiotemporal manifold (case one), or one can go the other way around (case two). In either case, the candidates for "spacetime" and "time" are non-fundamental and it does not seem that one case makes use of more fundamental entities than the other (i.e., it does not seem as if "time" in case one requires a more fundamental candidate than does "spacetime" in case two). Given this it seems that the relevant candidates are equally fundamental, so "Is spacetime more fundamental than time?" is nonsubstantive if relationalism is true.[35] On the other hand, if substantivalism is true, then exactly one of time or spacetime is fundamental. If exactly one of these entities is fundamental, then whichever of the two is more fundamental is outright fundamental. Questions of comparative fundamentality that refer to a fundamental entity are substantive. So, "Is spacetime more fundamental than time?" is a substantive question iff substantivalism is true.

One might think that it is obvious that the question is substantive regardless of the truth of substantivalism, since contemporary physics has ruled out space and time in favor of spacetime, and we ought to follow physics on this matter. The reason for thinking this comes from accepting what Ulrich Meyer (2013) calls

---

[35] I assume the same is true for anti-realism, except the anti-realist will simply deny that the derived entity is time or is spacetime.

the Inseparability Argument. The conclusion of the Inseparability Argument is a conjunction: (a) "relativistic spacetime is an inseparable amalgam," and (b) "any attempt at treating space and time separately is bound to result in failure" (Meyer 2013, 123–24). The second conjunct seems to say that any theory that appeals to space and time rather than spacetime will be empirically inadequate. The first conjunct suggests that you cannot (partly) derive spacetime from time. So, the question is substantive even if relationalism is true because physics dictates that spacetime must be more fundamental than space and time: to hold that space and time are more fundamental will result in an empirically inadequate theory.

There are two ways to respond to this objection. The first is to show that (a) is false while maintaining (b) by constructing an empirically adequate spacetime from space and time. Meyer does just this: he shows how one can retrieve relativistic spacetime when one holds a substantivalist view of space and a relationalist view of time.[36] Such a construction shows the Inseparability Argument unsound, which only tells us that we cannot use the Inseparability Argument to get to the claim about substantivity.

The second way to respond is to note that the argument assumes that physics is a good guide to what is fundamental—or at least to what is more fundamental than other things. This assumption is questionable, however, as we'll see in chapters four and five. Without this assumption, the argument loses its teeth.

3.3.4 Are Any Questions About Time Substantive?

I've just argued that debating whether spacetime is derived from time (and space) is a nonsubstantive debate iff one is a relationalist. One might wonder what other questions about time are nonsubstantive. Specifically, one might wonder whether every question about time is nonsubstantive if one is a relationalist.

---

[36] He also shows how to do this on his preferred account of time, which he calls a "modal view of time".

At the very worst, there is one question about time that is substantive: Is time fundamental? From this we can quickly see that one of the questions from the taxonomy is chapter two is also substantive: Is time an independent thing? The same holds true of the other two questions discussed in the taxonomy: whether reductionism about the direction of time is true and whether reductionism about tense is true. To see this, though, we need to rephrase the questions slightly.

If time is not a fundamental entity, then (given the remarks on substantivity) we should adopt a functionalist attitude towards time. Rather than ask "What is time?", we should focus on the roles that time plays. Determining the roles that time plays is largely conceptual, but once we have the roles that time needs to play, we then look at the fundamental entities in our ontology and see if any of them or anything that can be derived from them is able to fill those roles. This suggests a kind of paraphrase strategy for asking substantive questions about time: for any question about time, figure out what role the question is asking about, and then ask whether there is something that plays that role. Proceeding in this way does not preclude the possibility that time is fundamental: if there are no entities that fill all of the roles time needs to play, then that is evidence that time should be included as a fundamental entity (or is evidence that anti-realism about time is true). Likewise, if time is a fundamental entity, we would expect that questions of the form "Is there some thing that plays temporal role R?" will have an affirmative answer.

This paraphrase strategy presupposes that we are clear on what roles time plays. In fact, you will end up with a nonsubstantive question if you're not clear about the role in question: there might be multiple candidates for the role (in that there might be multiple predicates that are candidates for the role in question), and whether the answer to the question is true or false depends on which candidate we choose. For this reason, the next chapter aims to clarify the roles that time plays.

We can now see a way to ask substantively whether reductionism about tense is true and whether reductionism about the direction of time is true. Consider first reductionism about tense. As noted in chapter two, reductionism about tense is the thesis that one can give a description of reality using only tenseless statements, and that that description will be complete and accurate. (And recall that Kit Fine and I differ on our use of reality: while I say that anything that exists is real, he says that it is only the fundamental that is real.) From this, one might think that the appropriate question to ask is "Are tensed statements fundamental?". If Kit Fine is right about reality being composed of facts, then that is a suitable question to ask. But the Aristotelian will not think that any statements are fundamental, so "Are tensed statements fundamental?" and "Are tenseless statements fundamental" will both receive negative answers. The better question for the Aristotelian to ask is "Can every tensed statement be derived from tenseless ones?". An answer to this question will settle the question about reductionism: reductionism about tense is false iff some tensed statement cannot be derived from any tenseless statement(s).[37]

Reductionism about the direction of time is the thesis that time "goes" this way rather than that because causation, or entropy, or some other such thing "goes" this way rather than that. In chapter two I noted that one can make this question a bit more precise by thinking of time as a set of times, and that the set of times are ordered by a relation that is at least asymmetric and natural. Reductionism about time then becomes a thesis about whether there is something that induces such an order on the set of times. This is easy to paraphrase as a substantive question: Do substances induce an asymmetric relation on the set of times?

---

[37] A second way to proceed is to use Fine's theses for how one can be an anti-reductionist about tense and use those questions to paraphrase the debate about tense. For instance, the Coherence thesis, that reality is not irreducibly incoherent, could be used to ask whether a substance ever has only one internally coherent state. (This is motivated by the thought that change seems to require possessing incompatible properties.)

3.4 Conclusion

In this chapter I've introduced the metaphysical framework within which I will present and defend my view of time. This framework is Aristotelian in spirit: it posits a hierarchical ontology, where the different levels are related by relations of abstraction. According to this framework, existence is cheap: something exists provided that it is either fundamental or derivable from something fundamental. I offered a semantics for abstraction, which is one way of talking about derivation. This framework has an important upshot with respect to substantivity and verbal disputes. After characterizing substantivity, I showed how one question in the philosophy of time—whether time is more fundamental than spacetime—is substantive iff substantivalism is true. Moreover, the theses I introduced in chapter two are all substantive theses, which is a good sign for a taxonomy. In the following chapters I present and defend my view of time. I begin in chapter four by discussing some desiderata (several of which were hinted at in this chapter) that any relationalist view of time must address. Chapter five presents my view of time, while six and seven argue against rival views.

CHAPTER FOUR

Requirements For Relationalism

In this chapter I talk about desiderata for a relationalist view of time. Some of these desiderata are specific to relationalism but others are not. I will discuss these desiderata under three different groups. The groups are not disjoint: some of the desiderata are equally at home in one group as they are in the other. Using three different groups makes it easier to keep track of the big picture. The three groups that desiderata fall under are Change, Physics, and the Folk Theory.[1] The desiderata in the first two categories are presented as challenges or problems that need to be addressed. The Folk Theory is more open-ended: it offers data that a view needs to say something about. The more data a view of time can accommodate, the better; but dismissing some datum is permissible, as long as it is done for a good reason.

4.1 Change

I was less than five feet tall. Today, I am more than five feet tall. I've changed. And it really was *me* who changed: *I* was the one who was less than five feet tall and *I* am the one who is more than five feet tall. This kind of change is a change in my intrinsic properties.[2] *Being less than five feet tall* and *being more than five feet tall* are incompatible properties: today I cannot be both more than five feet tall

---

[1] Ulrich Meyer claims that whether a view of time adequately handles the requirements of these categories "suffice[s] to settle" whether that view is correct (Meyer 2013, 6). While Meyer says what it means to adequately account for change and does show how his view is consonant with contemporary physics, he does not spend much time talking about the folk theory of time.

[2] This is one kind of change, and the only one I will deal with. As Mortensen (2011) points out: "The most general conception of change is simply difference or nonidentity in the features of things" (S1). We can also talk about spatial change; e.g., the change in height of Mount Kilamanjaro from the base of the mountain to the top.

and less than five feet tall. The Problem of Change is the problem of making sense of how something can have incompatible properties at different times.[3]

Sally Haslanger (1989, 4–6) puts the Problem of Change in a perspicuous form. We start with two principles about change:

PER: There are some objects which persist through alteration, i.e., through the gain and/or loss of a property.

PI: If A persists through a change, then A must be identical to something before the change, and identical to something after the change.

These principles are supposed to capture our intuitions about change. We then add a plausible principle about identity, Leibniz's Law:

LL: If x is identical to y, then x has property F iff y does.

But now we're in trouble. A leaf outside my window is orange. The leaf was not always orange, though. According to PER, the very same leaf persisted through the gain of *being orange*. The leaf changed. If the leaf is an object that persists through alternation, then, as Haslanger points out, we are left with a trilemma. After the change, the leaf is identical to something that is orange, the leaf is not identical to something that is orange, or the leaf is not identical to anything at all. The first option is inconsistent with PER; the second option, with LL; and the third, with PI (Haslanger 1989b, 6).

It would be undesirable to accept any one horn of the trilemma. Both LL and PI "seem to be quite basic to our intuitions about existence and identity" (6). But if we accept LL and PI, we must deny that some objects persist through alteration, i.e. accept that nothing persists through alteration. Haslanger notes that one way to take this is to hold that objects are destroyed through alteration: "a wall is destroyed as it is painted, a tree is destroyed as it blooms, the candle cannot exist

[3] There is also the related problem of coming into and going out of existence. The problem stated in the text is the problem of temporary intrinsics: the problem of how "ordinary objects persist through changes in their intrinsic properties" (Haslanger 1989a, 119).

long enough to change its shape" (Haslanger 1989b, 6). Another way to deny PER is to deny that change happens at all. Neither options seems attractive. But if we hold on to PER, "we must revise our notions of existence and identity" (6).[4]

Solving the Problem of Change has an easy part and a hard part. While nothing can be both red all over and green all over, something can be green in one place and red in another. One could make the same move to solve the Problem of Change. After all, the changes mentioned above talked about how an objects have different properties at different times: the leaf was green but now it's orange. The tense of the verbs is important. As long as we're careful about how we speak, we can maintain PER, PI, and LL. Problem solved.

As Haslanger (1989b) notes, there are four ways spell out how to be more careful with our words:

(i) The-leaf-at-t is orange.

(ii) The leaf is-green-at-t.

(iii) The leaf is-at-t green.

(iv) At t, the leaf is green.[5]

So, the easy part of solving the Problem of Change is recognizing that one of these options allows us to hold on to PER, PI, and LL. The hard part of solving the Problem of Change is figuring out which of these options is correct.

Formally, the above views are on par with respect to solving the Problem of Change. If we were to express each formula in first-order logic, we would find that each view avoids contradiction by modifying the syntax for predicates: the arity of every predicate must increase by one to allow for a temporal index. So, the unary

[4] Haslanger's language suggests that LL and PI stand or fall together, but it is not clear why that would be the case.

[5] As Haslanger notes, these four solutions "are underdescribed" and meant "to be general and suggestive rather than technical" (Haslanger 1989b, 25, n. 9).

predicate "O(x)" (read as "x is orange") now needs to be the binary predicate "O(x, t)", and how we read that depends on which of (i)–(iv) we adopt.

Insofar as we want our language to reflect our ontology, the approaches differ in their metaphysical commitments because they differ in their semantics for "O(x, t)". To put that another way: insofar as we want our semantics to be depraved, each of (i)–(iv) expresses a different metaphysical commitment.[6] A depraved semantics is to be contrasted with a pure semantics.[7] Dean Zimmerman offers a helpful explanation of the difference:

> A "pure semantics" . . . need not be related in any significant way to the ostensible subject matter of the language being studied. It matches up entities with bits of the object-language, and the entities to which it appeals need only be sufficiently complex to model logical relations among interpreted sentences. A "depraved" semantics is supposed to do quite a bit more. The things it uses to explicate the meaning of a sentence should seem, intuitively, to have something to do with the meaning of the sentence; and the jobs associated by the semantics with parts of the sentence (e.g., referring to objects, attributing properties to things, referring collectively, etc.) should seem to be what they are actually being used to do. (Zimmerman 2005, 414)

Once we've determined that a semantics is supposed to be depraved, we can then consider how accurately the semantics reflects the underlying ontology. In this respect, depravity is not all-or-nothing: "a semantics is more depraved the more tightly it is tied to the true subject matter of the target sentences and (what the theorist takes to be) the true ontology" (415). (Analogously, once we've determined that a scientific model is supposed to be a literal depiction of the world, we can then consider how well the model succeeds at that goal. For instance, some models in Newtonian physics are supposed to depict how masses move on a plane. Models on

[6] Cf. Lowe (2005) and Lowe and McCall (2003, 2006), who dispute the claim that three-dimensionalists and four-dimensionalists do not espouse fundamentally different metaphysical pictures; that is, they dispute the claim that there is a difference in metaphysical commitment given a depraved semantics for (i)–(iv).

[7] This terminology comes from (Plantinga 1974).

which there are frictionless planes are less accurate (or less depraved) than models that allow for friction.) So, the more depraved two semantics are, the more we see the differences (and similarities) in their metaphysical commitments.

A depraved semantics for describing change is related to the debate over persistence. "Persistence" is the neutral word in this debate. We take it as a datum that some thing persists, that, "somehow or other, it exists at various times" (Lewis 1986, 202). But offering a way to describe change is not the same as explaining how things change.[8] Each of (i)–(iv) offers a different way to describe how things have temporary properties, but does not go so far as to offer an explanation for that change. The debate over persistence is closely tied to the philosophy of time, but it is not relevant for present purposes. The moral here is that a depraved semantics that affords us an "atemporal perspective" from which to describe change allows us to solve the problem of change. Introducing a temporal index into statements offers us exactly this atemporal perspective from which we can describe change (Hawley 2001, ch. 1).

Describing change from an atemporal perspective is not the only way to address the problem of change—but it is the most convenient.[9] As we'll see in the next section, any view of time needs some way of speaking atemporally in order to account for physics. Given that the relationalist needs to derive a temporal order to account for physics, she might as well kill two birds with one stone and use the temporal order to offer a semantics for change as well. So, I am going to operate under the assumption that one of the aforementioned ways of introducing temporal indicators

---

[8] Wasserman (2016) argues that most theories of persistence end up falling short of explaining how things persist. For instance, most perdurantists do not say how "facts about persistence are *grounded in*, or obtain *in virtue of*, facts about temporal parts"; instead the focus is on the existence of temporal parts (244). For an overview of the main positions in the debate see (Hawley 2001).

[9] In S7 of chapter one, Hawley (2001) considers how one might describe change without an atemporal perspective.

is the way to address the problem of change. So, our first requirement on a view of time is that a view of time must be able to offer a depraved semantics for one of the four ways of introducing temporal indicators.

4.2 Physics

An adequate theory of time must be able to express our best physical theories. The most prominent objections to relationalism contend that relationalism is unable to meet this desiderata. These physics-based objections to relationalism make use of a distinction between scientific theories and scientific models. This distinction is similar to the distinction between a theory and a model-theoretic semantics in formal languages. In both cases, the theory offers a set of sentences; in a good model, these sentences will be true. Moreover, scientific models display something like the semantic depravity that was discussed in the previous section. No scientific model reaches utter depravity, but (some) scientific models are meant to give us a literal description of the world: whatever entities are posited in the model are taken to be part of the furniture of the world.[10] Of the four objections we will consider, two claim that the relationalist cannot endorse a realist or a depraved reading of the (now) standard physical models that include fields in the domain of objects. The other two objections claim (i) that the General Relativity (GR) entails a certain set of sentences and (ii) that the relationalist cannot offer a model in which those sentences are true.

Even if they don't require it, the physics-based objections to relationalism that we will now consider all appeal to the standard interpretation of GR. The standard

[10] This is how a scientific realist reads these kinds of models. A scientific anti-realist, on the other hand, won't take scientific models as literal descriptions as reality. Instead, the anti-realist might say, for instance, that our best scientific models tell us about the *structure* of reality, not its furniture. Of course, the extent to which a model should be read literally depends on the kind of model (hence the qualifier in the text). Some models of phenomena are intended to be only idealizations or analogies. For instance, the billiard ball model of gas is an analogical model; even if we're scientific realists, it would be a mistake to read this model as a literal depiction of gas.

interpretation of GR talks about a thing called spacetime. Thus, one of the entities in models for GR is spacetime. GR is one of our best physical theories, though it is most likely false—for it is incompatible with the other frontrunner for best physical theory, quantum mechanics. Bradley Monton provides a succinct explanation of the matter:

> Some of the evidence for quantum theory (from, for example, the two-slit experiment) suggests that a particle can be in a superposition of different positions. But in general relativity, where the curvature of spacetime is based on the distribution of matter, there is no way to have a superposition of spacetimes. Also, some of the evidence for general relativity involves experiments done with precise clocks; these experiments show that clocks in strong gravitational fields run slow compared to clocks in weak gravitational fields. But according to quantum theory, ideal clocks run at the same rate regardless of the strength of the gravitational field they are in. (Monton 2011, 143)

Nonetheless, GR is approximately true; so, it is plausible that the physical interpretation of the theory that replaces GR (and quantum mechanics) will entail some of the same ontological claims that GR does. Thus, the extent to which relationalism has trouble expressing some of the claims that follow from GR (such as those about spacetime) is evidence that relationalism will have trouble expressing some of the claims that follow from whatever physical theory comes next.[11] (As we'll see, some of the objections use GR only to make the objection more concrete; the crucial features of the objection does not depend on the truth of GR.)

[11] I know of no objections to relationalism that appeal to quantum mechanics. And though there are attempts to reconcile the GR and quantum mechanics, none are developed enough to provide compelling arguments for or against a relationalist view, or any view of time for that matter. For instance, Monton (2006) takes one interpretation of loop quantum gravity to defend presentism; yet his argument makes two assumptions: (i) loop quantum gravity is the physical theory that will prevail, and (ii) his interpretation of loop quantum gravity is an interpretation of the theory. Wüthrich (2010) responds to and questions Monton's second assumption.

4.2.1 Field's Problem of Fields

Hartry Field (1984) raises both kinds of objections for relationalism. The first of his two objections that we'll consider is the problem of fields. The problem of fields is this: the relationalist cheats if he admits fields into his ontology, but without fields he cannot make sense of contemporary physical theories, which are field theories. If the relationalist admits fields into his ontology, then a field theory has to be seen "as postulating entities whose geometric properties are exactly the same as the geometric properties that the substantivalist ascribes to space-time" (41–42). Field is obviously suspicious of this move: "Small wonder that after giving field theories a strained interpretation according to which fields are entities that have the structure of space-time built into them, a separate space-time is then dispensable" (42). According to Field, "on an interesting version of relationalism, fields are just as much a fiction as is space-time" (41).

If fields are just as much a fiction as spacetime, then, Field claims, the relationalist cannot make sense of contemporary physical theories. Contemporary physical theories are field theories. Field theories predict and explain "the behavior of matter in terms of fields" (40). Field theories accomplish this by employing causal predicates "that apply directly to space-time points or regions" (40). Given this understanding of field theories, the relationalist cannot make sense of such theories. For field theories assign values to points and regions of spacetime regardless of whether matter occupies the point or region (e.g. electromagnetic field theory assigns "to each point in space-time an electromagnetic intensity") (40). But on a relationalist view, it is nonsense to talk of assigning values to points and regions that are not occupied by matter: there are no such things! So, the relationalist cannot predict and explain the behavior of matter in terms of fields, which means that he cannot accept any field theory.

This doesn't spell disaster for relationalism, but it does present the relationalist with a challenge. For a physical theory "to accord with anything reasonably called relationalism, ... a relationalist physical-theory would have to predict and explain the behavior of matter in terms only of that matter and other matter" (Field 1984, 40). Field calls such a theory an action-at-a-distance theory. The challenge to the relationalist is to show how one can replace field theories by action-at-a-distance theories, i.e. to show how the fields employed in field theories are "dispensable constructs" (40).

Field's argument hinges on the claim that field theories apply causal predicates directly to spacetime. For the substantivalist this view of field theories is a boon, for it means that "acceptance of a field theory is not acceptance of any extra *ontology* beyond space-time and ordinary matter, it is merely acceptance of an added sort of ideology" (41). But such an obvious appeal to spacetime looks pretty bad, especially since Field does not defend this view—or at least strike down alternatives that less clearly presuppose the falsity of relationalism.[12] But I won't discuss weaknesses in Field's argument here. Instead I will assume that his view of fields is correct. If it is, the problem of fields leaves the relationalist with a dilemma: either show that it's not cheating to admit fields into one's ontology, or show how to dispense with field theories in favor of action-at-a-distance theories.

4.2.2 A Substantive Debate?

Tim Maudlin (1993) says that, in the context of GR, the relationalist's best option is to endorse a field ontology—though he agrees with Hartry Field that this

[12] For instance, why not say that field theories employ causal predicates that apply directly to fields? Then, assuming the relationalist can answer the charge of cheating, the relationalist could make sense of field theories. This alternate view of field theories is, moreover, in accord with how Rovelli (2006) interprets the advent of general relativity. Recall that Rovelli says it is only because of convenience that we call the gravitational field "spacetime". The more honest interpretation of relativity theory says that there is no one thing that is spacetime; instead there are a number of fields, one of which is the gravitational field.

raises trouble for relationalism. Unlike Field, Maudlin does not think that the relationalist cheats by admitting fields into her ontology. Rather, Maudlin holds that the distinction between relationalism and substantivalism turns into a merely verbal dispute, and the dispute is over an ontology that looks more like substantivalism than relationalism.

Maudlin's argument is straightforward: GR pushes the relationalist to adopt a field ontology; but if the relationalist adopts a field ontology, the debate between relationalists and substantivalists turns into a merely verbal dispute. Here is Maudlin on the first premise:

> Ironically it is exactly the absoluteness of Newtonian space and of Minkowski spacetime that allows the relationist to treat them as fictions yet still exploit their mathematical utility. Because the geometrical structure of these spacetimes is fixed independently of the matter in them, one knows a priori the nature of the manifold into which the particle trajectories must be embedded. ...
> In the GR, though, the spatiotemporal structure of the embedding space is not given a priori. Total information about the relations between material particles may not fix the structure of the whole spacetime sufficiently to permit prediction. (Maudlin 1993, 199)

Without the ability to predict the behavior of matter, relationalism cannot offer an empirically adequate theory. So, the relationalist needs to get the structure of spacetime from another source. In this case, that other source is an ontology that contains fields.

The second premise of Maudlin's argument is a bit more subtle. Once the relationalist admits fields, it looks like relationalism collapses into substantivalism. But, Maudlin claims, there are still two metaphysical differences between the views:

(1) For the substantivalist, the fields as they actually are and the fields as they would be were every field statically shifted in some direction are distinct possibilities; this is not the case for the relationalist.

(2) For the substantivalist, fields occupy regions of spacetime but do not constitute spacetime; for the relationalist, fields constitute spacetime.[13]

He then argues that, in the context of GR, the differences between substantivalism and relationalism nearly evaporate. For instance, the static shift mentioned in 1 "cannot be formulated in any realistic (i.e., nonhomogenous) General Relativistic spacetime" (Maudlin 1993, 201). This prompts Maudlin's conclusion that, "insofar as the debate [between substantivalism and relationalism] is motivated by the considerations voiced by Leibniz and Newton, the substantivalist/relationalist debate has at last resolved itself into a purely verbal dispute" (201). Leibniz and Newton were concerned with whether certain arrangements of matter yielded distinct physical situations; i.e., they were concerned with the kinds of distinctions mentioned in 1. If the distinction between substantivalism and relationalism is motivated on those grounds (alone), then GR resolves the debate into a merely verbal dispute.

It might look like 2 saves the substantivity of the debate. But Maudlin argues that if the relationalist accepts fields into her ontology and intends to use them as a surrogate for substantival spacetime, she has three options for her field ontology, none of which help her cause: (i) "all fields are everywhere nonzero due to vacuum fluctuations"; (ii) a Higgs field that has "no state in which it does not exist, because it has no state characterized by both minimal energy and zero-field intensity"; and (iii) the field is a metric field, which will exist "since its 'vacuum' state is the Minkowski metric, not a zero tensor" (201). Maudlin says that the first two are "embarrassing" because they are physically extravagant and the third is, from the relationalist's point of view, as objectionable as substantival spacetime (201–02). The only view of spacetime that is plausible "is much more the heir of Newton than of Leibniz" (202).

---

[13] Another point of distinction: the relationalist must hold that wherever the field exists, it has a non-zero value (Maudlin 1993, 201). Maudlin does not discuss discuss the possibility that fields are mere ideology for the substantivalist but are part of the relationalist's ontology.

4.2.3 Morals: Round 1

The first round of physics-based critiques leaves the relationalist with a dilemma. The relationalist is pushed towards a field ontology so that he can make sense of contemporary physical theories. But then it seems that relationalism either cheats or ends up being a different name for substantivalism.

Hartry Field's and Tim Maudlin's arguments against relationalism each take models with fields at face-value. They then argue that relationalism is in trouble if the relationalist attempts to take these models at face-value. What is unclear—and what I will exploit in the next chapter—is what it means to take a model at face-value. One common complaint against scientific realism is that it requires that models be approximately true, but the scientific realist cannot offer a satisfactory account of approximate truth. This is a problem since we are only to take as literal depictions of the world those parts of the model that are true. This is not the unclarity that I will exploit. Instead, I want to consider these objections through the lens of depravity. Scientific realism requires a certain level of depravity—the objects in a model need to be suitably connected to the world in order to be approximately true—but what *kind* of depravity does it require? The kind of relationalism that I defend does admit that there are fields—but they are not fundamental. The question that I must answer, then, is "Is it really realism?". Since it is a cost to have to give up scientific realism, if realism about our best scientific models requires that fields are fundamental entities, then the relationalist is in trouble.

4.2.4 Friedman's Critique

The problem raised by Maudlin comes from understanding the difference between relationalism and substantivalism in a way introduced by Friedman (1983), who raises the second kind of objection to relationalism. This kind of objection claims that relativity theory entails a certain set of sentences, and that relationalism cannot offer a model in which these sentences are true. These objections say, in effect, that if relationalism is true, there just isn't enough stuff to do physics. We will consider Friedman's objection from expressive power and then Field's problem of quantities.

Any physical theory has a number of theoretical properties and relations that need to be defined. Friedman contends that relationalism may not be able to define all of these properties and relations. To show this, he argues that relationalists and substantivalists must differ in their understanding of the relationship between two set-theoretic models for a physical theory. This difference in understanding arises from the physical interpretation that the relationalist and substantivalist each gives to the two set-theoretic models. He then uses that difference to show how relationalism not only faces a problem with defining all the theoretical properties and roles that need to be defined, but also appears to lack a level of theoretical unity that substantivalism has.

The two models that Friedman uses are supposed to represent the big ontological difference between relationalists and substantivalists. For the relationalist, the only spatiotemporal locations that exist are the ones that are, as Friedman puts it, "occupied by concrete physical events" (Friedman 1983, 217). (It's not entirely clear what Friedman means by "concrete physical event": in one place it looks like concrete physical events are simply physical objects (62) and in another they appear to be "material objects or processes" (217). Given this, I stick to "concrete physical events" throughout.) The substantivalist, by contrast, admits many more spatiotemporal locations than just those that are occupied by concrete physical events. For the substantivalist, any spacetime points that exist, exist regardless of whether they are occupied by concrete physical events. Accordingly, the model that a substantivalist affirms as an accurate depiction of the world will have more stuff in it than the model affirmed by a relationalist.

The model affirmed by the substantivalist contains every spacetime point, regardless of whether it's occupied by a concrete physical event, whereas the model affirmed by the relationalist contains only those spacetime points that are occupied by a concrete physical event. Let's call these models M and P, respectively. Following Friedman, these will be models for special relativity. M consists of a four-dimensional manifold, $\mathcal{M}$, and a function $I : \mathcal{M} \times \mathcal{M} \to \mathbb{R}$, which is the Minkowski interval function.[14] Using this function, the value for the interval between two spacetime points is calculated as $\sqrt{dx_1^2 + dx_2^2 + dx_3^2 - dt^2}$, where dx_1, dx_2, and dx_3 represent the difference between the spatial coordinates of the two spacetime points, while dt represents the difference between the time coordinates of the two spacetime points.[15] P consists of the set $\mathcal{P}$, where $\mathcal{P} \subset \mathcal{M}$ such that the members of $\mathcal{P}$ are those points of $\mathcal{M}$ that are occupied by concrete physical events, and the function I', which is a restriction of the domain of I to $\mathcal{P} \times \mathcal{P}$ (written as $I|_{\mathcal{P}\times\mathcal{P}}$). We then have $M = \langle \mathcal{M}, I \rangle$ and $P = \langle \mathcal{P}, I' \rangle$. The substantivalist will say that M is an accurate reflection of what exists whereas the relationalist will say that P is.

The relationalist and the substantivalist each need to offer a physical interpretation of the relationship between M and P. For the substantivalist, this is easy: mathematically, P is a submodel of M and this is quite literally true. $\mathcal{M}$ is a manifold of spacetime points and $\mathcal{P}$ is just those spacetime points that happen to be

---

[14] To make this argument work when considering general relativity we will need a Riemannian metric rather than the Minkowski metric. Rather than have one function that tell us the distance between any two points, a Riemannian metric is a collection of inner products: for every $p \in \mathcal{M}$, $g_p : T_p\mathcal{M} \times T_p\mathcal{M} \to \mathbb{R}$, where $T_p\mathcal{M}$ is the tangent space of p. Rather than using a pair of points to determine the value of the metric function, the value is instead determined relative to each point in $\mathcal{M}$. Given this change, we can suitably modify the argument in the text—which is important since, as Tim Maudlin notes, the relationalist will be able to mimic Minkowski spacetime because of its structural regularities: it is general relativity that is really supposed to get the relationalist in trouble. Nonetheless, since special relativity makes for a cleaner presentation, I stick to it in the main text.

[15] Friedman splits up the interval function into three different relations: timelike separation, spacelike separation, and null (lightlike) separation (Friedman 1983, 217). For present purposes this is an unnecessary complication.

occupied by concrete physical events. Likewise, the values for I' just are the result of restricting our attention to the distances between spacetime points that are occupied by concrete physical events. On this view (which Friedman calls the submodel view) truths about P are explained in terms of M: the larger structure M "is an *explanation* ... of the properties of the smaller structure" P (Friedman 1983, 220).

Since the relationalist holds that P is the more accurate model of what there is, she cannot endorse the submodel view. The relationalist must maintain that M is not an explanation of P. Instead she must adopt what Friedman calls the embedding view. According to the embedding view M is "only a *representation* of the properties of the smaller structure [P]: elements of the latter are only correlated with or mapped onto elements of the former" (217). For instance, the relationalist will hold that I' reveals a certain structure to $\mathcal{P}$. On the embedding view, we can say that (part of) $\mathcal{M}$ has the same structure as $\mathcal{P}$ because we can use I' to define (part of) I. So, even though it is still correct to describe I' as $I|_{\mathcal{P}\times\mathcal{P}}$, part of the range of I is explained by the range of I', which is a reversal of the explanation given by the submodel view. Note that this does not offer any explanation for the rest of M. In fact, as I'll discuss below, this is a source of trouble for the relationalist: the relationalist needs to show that (and how) I is the (unique up to isomorphism) extension of I'; for if there are multiple (non-isomorphic) ways to extend I' so that it is defined over all of $\mathcal{M}$, then there will be some points in $\mathcal{M}$ such that once extension of I' says that those objects are d units apart and another extension of I' says that those objects are some other distance apart—which is an objectionable kind of indeterminism.

One final difference (which Friedman doesn't discuss) between the submodel view and the embedding view is what the members of $\mathcal{M}$ and $\mathcal{P}$ represent. On the submodel view, it is fine to say that the members of $\mathcal{M}$, and therefore $\mathcal{P}$, represent (or even are) spacetime points, since $\mathcal{P}$ just is a subset of $\mathcal{M}$. This is not the case for the embedding view, however. On the embedding view, the members of $\mathcal{P}$ represent concrete physical events. The relationalist will not have a problem embedding those events in $\mathcal{M}$, i.e. saying that some of the members of $\mathcal{M}$ are or represent concrete physical events. But $\mathcal{P} \subset \mathcal{M}$, so the relationalist needs to say what the remaining members of $\mathcal{M}$ represent. (I refrain from saying more here since this will come up when discussing Hartry Field's Problem of Quantities.)

Given this understanding of the relationship between substantivalism and relationalism, Friedman poses a problem of expressive power to the relationalist. The problem has two parts. The idea behind the first part of the problem is that the relationalist might find herself in the following situation: (i) there are some theoretical properties and relations $R_1, \ldots, R_n$ that need to be defined; but (ii) since her domain of objects is limited to concrete physical events, she can only define $R_1, \ldots, R_m$, where $m < n$; so (iii) there are some theoretical properties that are not well-defined, which means that relationalism lacks the expressive power to state the physical theory. Of course, this problem is conditional upon the relationalist finding herself in such a situation. Nonetheless, Friedman sees this as a serious worry: the fact that such a scenario is possible means that there is no guarantee that relationalism can state our best physical theories, and that is worrisome.[16]

Friedman defends (i) and (ii) by appealing to a distinction between a theoretical structure $\mathcal{A}$ and an observational structure $\mathcal{B}$. As with M and P above, so too with $\mathcal{A}$ and $\mathcal{B}$: we can view $\mathcal{B}$ "as a substructure of $\mathcal{A}$," or we can say that $\mathcal{B}$ is embeddable into $\mathcal{A}$, which means that we "construe our use of $\mathcal{A}$ as a mere *representation* of the properties of $\mathcal{B}$" (Friedman 1983, 236). A big advantage of the substructure view is that if "$\mathcal{B}$ is literally a submodel of $\mathcal{A}$, then $\mathcal{A}$ induces

[16] A Leibnizian might welcome just such a result, though: that is one way to take the Leibniz shift arguments: the static and kinematic shifts yield distinct possibilities only if there are certain theoretical properties and relations—but, the Leibnizian will say, there are no such properties: the fact that a relationalist cannot define a property or relation shows that that property or relation is not a theoretical property or relation.

theoretical properties and relations on objects in B, properties that are in general necessary for stating accurate laws about these objects" (Friedman 1983, 240). But, for the same reasons as were stated above, the relationalist must say that $\mathcal{A}$ is only a representation of $\mathcal{B}$. For the relationalist, the embedding view has the benefit that $\mathcal{A}$ "can be thought of as a purely mathematical object" (236). The problem with this view is that embedding $\mathcal{B}$ into $\mathcal{A}$ might not "induce the necessary theoretical properties and relations" (240).[17]

To show how $\mathcal{B}$ might fail to induce the necessary theoretical properties and relations, Friedman offers the following proof.[18] Let $\mathcal{A} = \langle A, R_1, \ldots, R_n \rangle$ and $\mathcal{B} = \langle B, R'_1, \ldots, R'_m \rangle$, where $m \leq n$. $R_1, \ldots, R_n$ are functions that take members of A and map them to $\{0, 1\}$, and $R'_1, \ldots, R'_m$ are are functions that take members of B and map them to $\{0, 1\}$. We can think of $R_1, \ldots, R_n$ as all of the theoretical properties and relations that need to be defined (which is (i) from above). Suppose that $\mathcal{B}$ is embeddable into $\mathcal{A}$. If $\mathcal{B}$ is embeddable into $\mathcal{A}$, then there is a one-one function $\phi : B \to A$ such that we can map $\mathcal{B}$ onto $\mathcal{A}$ in a way that preserves the structure of $\mathcal{B}$. For simplicity, suppose that ϕ guarantees that, when $\phi(b) = a$, $R_i(a) = 1$ iff $R'_i(b) = 1$ for $i = 1, \ldots, m$. (In less technical language: ϕ guarantees that R'_i is mapped to R_i for $i = 1, \ldots, m$.) Now suppose that there is some R_j, for $j > m$ and that we cannot define R_j in terms of $R_1, \ldots, R_m$. For simplicity, suppose that R_j takes only one argument. Then there is another one-one function $\psi : B \to A$ that differs from ϕ in the following respect: for some $b \in B$, $R_j(\phi(b)) = 1$ but $R_j(\psi(b)) = 0$ (i.e. one mapping says that b instantiates R_j while the other says that b doesn't). This means that we have two ways to embed $\mathcal{B}$ into $\mathcal{A}$ but the embeddings disagree on whether some element in the observational structure instantiates a theoretical property. This

[17] Friedman actually claims that the embedding view *will not* induce the necessary properties and relations, but as I've pointed out, that is too strong a claim.

[18] This proof is a slightly modified version of the one that Friedman gives; all of the crucial steps are the same; I've simply cleaned it up in some places and expanded it (for clarity) in others.

means that the theoretical property R_j is not well-defined. But, by hypothesis, R_j is one of the theoretical properties that needs to be defined. So, if the relationalist finds herself in this situation, she will be unable to fully state the physical theory, which means relationalism lacks expressive power. The first part of the challenge to the relationalist, then, is this: saying that $\mathcal{B}$ is embeddable in $\mathcal{A}$ (or that P is embeddable in M) is not enough to guarantee that we can state our best physical theories.[19]

Friedman concedes that one way around the first part of the challenge is to introduce more primitive relations to $\mathcal{B}$ so that we can account for the necessary theoretical structure (Friedman 1983, 241). But this is only a stopgap. That observational structures might not be rich enough to define all theoretical properties and relations points to the second shortcoming of viewing M as a mere representation. Viewing observational structures as submodels of theoretical structures has a unifying power that one cannot get if observational stuctures are embedded into theoretical ones (241–44). So, Friedman's objection of expressive power is this: the relationalist might not be able to define all theoretical properties and relations that need to be defined—but even if she can, her physical theory still lacks an overall unity that the substantivalist's theory does not.

4.2.5 Field's Problem of Quantities

The classic objection to relationalism is the problem of absolute acceleration, which is often demonstrated through Newton's rotating-bucket experiment.[20] In

[19] Cf. Maudlin (1993) on this point: he claims that the relationalist can employ the embedding strategy and recover the expressive power of physics when we limit ourselves to the Special Theory of Relativity; it is only when we move on to GR that the problem of expressive power resurfaces.

[20] As I noted in chapter two, the rotating-bucket experiment asks us to consider what happens to water in a bucket when the bucket begins to rotate, rotates for a little while, and then ceases to rotate. The thought experiment is supposed to support the conclusion that the behavior of the water cannot be explained solely in terms of relative motion, and therefore requires absolute motion (which Newton took as evidence for the existence of absolute space).

brief, the problem of acceleration is this: we need absolute acceleration, but the only way to get absolute acceleration entails substativalism.[21]

Field (1984) argues that Newton's rotating-bucket experiment is a special case of a more general problem for relationalism: the problem of quantities. The problem of quantities arises from a plausible "moderateness condition": "magnitude relations between physical things and numbers must always be generated from relations among physical things" (45). This condition is a semantic constraint: it tells us under what conditions sentences stating magnitude relations are true. This condition is easy to meet if spacetime has structural regularities: we can use representation theorems to generate numerical functions. A representation theorem will say that spacetime can be (accurately) represented by some mathematical object, in this case a four-dimensional manifold. Then, provided that we can define a metric on the manifold, we have a way to represent the distance between two physical things. Since the manifold, and therefore the metric, was chosen because it is an accurate representation of the structural regularities of spacetime, we can say that the magnitude relations are generated by relations among physical things, thus satisfying the moderateness condition.[22]

But if relationalism is true, spacetime does not have the requisite regularities. To see this, recall the two manifolds discussed above, $\mathcal{M}$ and $\mathcal{P}$. If we think of these as mathematical objects, the relationalist must say that $\mathcal{P}$ is the more accurate representation of spacetime since $\mathcal{M}$ includes points that do not represent anything, while every point of $\mathcal{P}$ corresponds to some physical thing. But this makes spacetime gappy. And, as was pointed out above, these kinds of gaps lead to indeterminism:

[21] Friedman raises this problem as well, but states it in different terms. He claims that "acceleration and rotation are essentially four-dimensional notions" (232). This creates a problem for the relationalist, who, Friedman claims, is most at home with three-dimensional notions.

[22] This holds even if there is not a unique representation for spacetime. What matters, as we'll see in the next paragraph, is that every numerical value can be traced back to a relation between points of the manifold, which can be traced back to a relation between physical things.

some ways of filling in the gaps will say that two objects are a certain distance apart, while other ways of filling in the gaps will deny that those objects are that distance apart. This does not entail that we cannot represent spacetime with a four-dimensional manifold. But if there are multiple ways of (accurately) representing spacetime that disagree on what magnitude relations hold between points of the manifold, then it is hard to see how those magnitude relations are generated from relations between physical things. For if two physical things bear a certain relation to one another, that relation should be represented in the same way in every structure-preserving mathematical representation of spacetime. In other words, it looks like the relationalist cannot satisfy the moderateness condition.

One reply (which Field is sympathetic to) is to forget about using numerical functions to satisfy the moderateness condition. Field is sympathetic to this reply since he rejects Platonism and holds that the most attractive form of relationalism will be nominalist friendly.[23] Nonetheless, Field claims that this does not free the relationalist from trouble—for the problem of quantities can be cast using only the relationalist's ideology. Say we have a congruence relation, so that we can say x and y are the same distance apart as w and z. We also need to talk about being twice the distance, thrice the distance, etc. The easiest way to do this is to invoke a

---

[23] His reason for holding this are, more or less: (i) substantivalism can satisfy the moderateness condition without endorsing Platonism (we saw how to do this in the previous paragraph); (ii) Platonism is an unattractive ontological commitment; so (iii), if relationalism can be defended only by endorsing Platonism, so much the worse for relationalism. Field does considers whether the relationalist could adopt moderate platonism—the view that there are abstract objects such as numbers and that "magnitude relations between physical things and numbers are conventional relations that are derivative from more basic relations that hold among physical things alone" (Field 1984, 44). His conclusion is that if the substantivalist can do without mathematical entities in a physical theory (as he thinks the substantivalist can), then "whatever ontological advantages there might be in dispensing with space-time would be far outweighed by the need to introduce mathematical entities which would otherwise be unnecessary" (47). So, a solution to the problem of quantities that appeals to numbers not only needs to show how numbers solve the problem, but also needs to be supported by an argument that the substantivalist cannot do without mathematical entities. Field's hopes with respect to discarding any form of Platonism are quite ambitious, so much so that it's not unreasonable to set this additional constraint aside, which is exactly what I plan to do.

fifth point u: x is twice the distance from y as w is to z iff there's some u such that x to u and u to y are each the same distance as w to z. This won't work for the relationalist because there might not be some fifth point. The only work-around is to take the relation as primitive; but this kind of reasoning looks like it will force the relationalist to admit an infinite stock of primitives. Further, having such primitives is bad because there is no stateable connection between these relations: we lack the ability to explain how the different distance relations are related. Field surveys three ways the relationalist responds and concludes that none are satisfactory. This objection, then, says that a spacetime theory entails a certain set of claims about magnitude, and that the relationalist cannot offer a model in which those claims are true. The reasoning is similar to that seen in Friedman's objection: there just isn't enough stuff.

These objections all assume a realist attitude towards scientific models. While the relationalist could avoid each of these objections by endorsing some variety of anti-realism about models, it is to the relationalist's advantage if he can answer the objections while maintaining realism. Thus, I won't entertain the possibility of an anti-realist stance towards scientific models when I answer these objections in the next chapter. What I will do is consider the connection between depravity and realism. It seems that the relationalist can consistently maintain a realist attitude towards scientific models even if the objects in those models are not fundamental.

4.3 The Folk Theory

We can think of a folk theory of X as a theory that endorses the claims about X that ordinary people are likely to endorse, or as a theory that is comprised of commonsense claims about X. This makes it hard to justify the claim one is giving *the* folk theory of X; it's likely that there are a family of folk theories about X. Nonetheless, it's less awkward to speak of *the* folk theory of X than it is to speak of *a* folk theory or of a family of folk theories. So, in what follows I will speak of the folk theory of time for the sake of convenience. The aim here is to put forth claims that would seem to be a part of any folk theory of time.

The folk theory of time serves as a good starting point for what is required of a view of time. While the folk theory of time does not have the final say about what time is or what time is like, respecting some aspects of the folk theory of time is important. In chapter two, we already saw that Aristotle thought one could not endorse everything the folk theory of time says: the folk theory says that time is composed of nows, but that thesis leads to contradictions when combined with other aspects of the folk theory, such as the passing of time. So, we should take the folk theory as providing data to be accounted for. Perhaps we take some datum literally and explain away others; but we must address it in some way. Here I am going to discuss what seem to be the most prominent parts of the folk theory of time: time's order, time's measure, time's flow, and time's modal profile.[24]

That time is ordered is suggested by the fact that we talk of events happening before, after, or at the same time as others;[25] and we also talk about past events, future events, and events happening now. For instance, a teacher will tell his students that stage coaches were used for transportation before cars were; or a doctor will

---

[24] I recently discovered that Baron and Miller (2014) have an explicit formulation of a folk theory of time. Given the above remark about the possibility of multiple folk theories, I only want to mention their view and remark on its similarities to what I present. Baron and Miller adopt a functionalist attitude towards the folk theory of time: time is "whatever it is, R, that is being tracked by our temporal phenomenology such that R possesses certain minimal features, F, where F includes features that are necessary for the existence of causation, persistence and change" (8). They note that our temporal phenomenology includes "experiences of temporal duration, temporal distance, and temporal ordering" (5), all of which are included in my version of the folk theory. They add that, in order to "adequately support the timeful phenomena" the folk theory of time must "be capable of: (i) rendering sensible an indexical version of 'now', (ii) supporting a difference between the past and future, (iii) underscoring the manner in which the world displays a past/future asymmetry and (iv) scaffolding the asymmetry of counterfactuals dependence" (6–7). Each of these fall under time's order; though time's flow also covers (ii) and (iii); and (iii) and (iv) are also partly a concern of time's modal profile.

[25] Indeed, van Fraassen even claims that "To say that things happen in time means in part that they happen in a certain order" (Van Fraassen 1970, 3).

tell her patient that he will feel better after he takes the medicine. In this respect, the temporal order is analogous to the spatial order. The spatial relations *in front of*, *behind*, *to the left of*, and *to the right of* are analogous to the temporal relations *before* and *after*. Likewise, the spatial relation *in the same place as* is analogous to the temporal relation *at the same time as*. And at a minimum the folk theory must respect the fact that there is an indexical use of "now" that functions like the indexical "here". It's true that I am now writing this sentence and you will be reading it later on, though it is also true that you are now reading this sentence and I was writing it—but which of the two is true depends on where we are in the order of events.

The analogy between the spatial order and the temporal order goes only so far, though. In general, there are more constraints on how things are arranged in time than there are on how things are arranged in space. It is easier to entertain the idea of material objects being randomly rearranged in space. It is more difficult to imagine events being randomly rearranged in time. For instance, it is not a controversial claim to say that the furniture in my apartment could be rearranged so that a painting is between my door and a bookshelf, even though the bookshelf is actually between the door and the painting. It is far more controversial to say that my thirteenth birthday could have happened before my birth.[26] This suggests that a folk theory of time says that there is something (e.g., counterfactual dependence or causation) that restricts the ways in which events can be ordered. Moreover, the distinction between the past and future also adds an asymmetry to the temporal order that seems absent from the spatial order.

[26] If you allow for Lewisian time-travel, this is true with respect to what Lewis calls one's personal time, though it may be false with respect to external time. (See (Lewis 1976, 146).) Nonetheless, the main point remains: the temporal ordering of events is still in some way constrained.

Related to ordering is measuring. A second piece of the folk theory of time is that the theory affords us some way to compare, quantitatively, what is in time. For instance, we compare the duration of events: it took Jim five minutes longer than John to finish the race. We also talk of temporal distance: it has been more than three years since I lived in New Jersey. So, it is not just that what is in time is ordered in a certain way: that ordering is such that we can quantitatively compare duration and temporal distance. This is also brought out in the fact that we use clocks and calendars to "keep track of time."[27]

The third main piece of the folk theory of time is that time passes or flows. While the metaphor suggests that it is time itself that flows or passes, it is the way that we speak of change that suggests the metaphor. We speak "of events as coming to be and passing away, as undergoing change over, or in, time" (Bardon 2013, 1). We also talk about how something which is now present—e.g., my typing this sentence—will soon be in the past. This gives what is often called a "dynamic" quality to time: what is present is always changing since the present becomes past and the future becomes present.

Finally we arrive at time's modal profile. A more folk-theoretic way to talk about this is the nature of the past, present, and future. A folk theory of time suggests that the (actual) past is fixed, though the past could have been different. The folk theory suggests that the future, however, is open, or yet-to-be-determined. For instance, yesterday I went cycling, but I could have gone running instead. This amounts to saying that the events that happened might not have happened, that the past is *modally flexible*. Of course, given the present, we may think that the past is necessary; but that is an innocuous kind of necessity. The kind of flexibility that this part of the folk theory holds is that the order of events might have been

[27] Cf. Bardon (2013), who does not include measuring as a part of the folk theory (even though he admits that time "certainly has something to do with measurement" (3): "we use calendars to track [the order] of time and clocks" to track the flow of time (1).

different altogether. (That said, it appears that time's modal profile partly explains why the order of events cannot be randomly rearranged as can pieces of furniture in the room: time's modal profile places some of the constraints on how events can be ordered.)

The above four claims are hallmarks of the folk theory of time. Upon observation one will realize that there is a higher-order principle governing the views that the folk theory endorses: time must be connected to material objects and the causal order. Time's order and flow are supposed to reflect the way in which material objects change, for instance. Likewise, modal flexibility reflects the thought that events are not (always) causally determined. So, the folk theory of time leaves us with five pieces of data that a relationalist view of time must account for. An overarching requirement is that time is connected to material objects and the causal order. A relationalist view of time should have no problem meeting this requirement since time depends on material objects and the changes they undergo. Assuming that our view of time has met that requirement, a relationalist view should also tell us about time's order, how time can measure changes and processes, what it means for time to flow, and how time is modally flexible.

Above I noted that the folk theory serves as a starting point for theorizing, but it is by no means a definitive guide. Indeed, this accounts for the variety of views on time. Views of time tend to regard some part of the folk theory more highly than others. For instance, Ulrich Meyer observes that "Spatial views like to draw attention to the pervasive use of spatial metaphors in temporal discourse" (Meyer 2013, 5). Meyer says that his "modal" view of time plays up "the fact that, in many natural languages, verbs are tensed" (5). Here we see the two main features of a folk theory regarded differently: the spatial views of time emphasize time's order and how that order is analogous to the order of space; the modal views find time's passing or flow more important and regard the tensed verbs in natural language as indicative of the nature of time. One reason for emphasizing some features of the folk theory more than others is that it appears that no theory of time can give equal weight to every part of the folk theory: there are some parts of the folk theory that have to be denied, explained away, or taken non-literally.

4.4 Summary

The desiderata for a relationalist view of time can be grouped into three categories: those dealing with change, those dealing with physics, and those dealing with the folk theory. The first two kinds of desiderata arose from problems that relationalism must address. The relationalist has sundry ways to deal with the last kind of requirement, since the folk theory gives data to account for rather than a problem to address. The discussion of these three categories left us with the following:

- The Problem of Change (S4.1)
- The Problem of Fields (SS4.2.1, 4.2.2)
- The Problem of Expressive Power (S4.2.4)
- The Problem of Quantities (S4.2.5)
- Connection with material objects and the causal order (S4.3)
- Time's order and measure (S4.3)
- Time's passage or flow (S4.3)
- Time's modal profile (S4.3).

It's now time to show how a relationalist, armed with an Aristotelian view of abstraction, can offer a theory of time that addresses all of these problems and desiderata.

CHAPTER FIVE

A View Of Time

In the last chapter we saw three kinds of desiderata for a relationalist view of time. First, the view must have the resources to solve the problem of change. The easy part of the solution is to say that we need to introduce temporal indices into our semantics; the hard part is arguing for a specific way of introducing those indices. Second, the view must be able to offer a rich enough model to account for our best physics. As we saw, the challenge for the relationalist is to show that these models do not require denying scientific realism. Third, the view must say something about the data we are presented with in the folk theory of time. As I pointed out, the folk theory is not a definitive guide to a theory of time; rather it presents us with ways that we talk about time. Any theory may take seriously some parts of the folk theory but not others. However, any view of time must have something to say about the data the folk theory gives us. In this chapter I will present my relationalist view of time. This chapter contains bald assertions about some parts of my view; some of these assertions will be (indirectly) defended in the next chapter, in which I discuss the competitors to my view. But the main defense of the view is in this chapter, for here we see that the view is a unified account of time that meets well all of the desiderata from the previous chapter.

5.1 The Metric and the Temporal Order

A relationalist can meet all of the requirements given in the previous chapter with a temporal order and a metric. Before getting to the hard work, I will briefly characterize what a temporal order and a metric are. I will then discuss what it looks like to derive these entities within an Aristotelian framework. And remember: since time is not a fundamental entity, a functionalist attitude is the appropriate attitude to have throughout—we're not looking for some specific entity but are instead concerned with filling certain roles.

Events and processes happen in or take time. Some events, like the signing of the Declaration of Independence, take place before others, such as the first man landing on the moon. The temporal order is supposed to reflect these truths. That is, the temporal order is supposed to reflect the fact that dinosaurs walked on the earth, and that they did so before the Wright brothers took to the sky. So the temporal order needs to tell us that things take place in time and that things take place in a certain kind of order. In other words, the temporal order needs some content, and it needs to order that content. The first bald assertion in this chapter is about where that content comes from: to tell us that things take place in time, the temporal order needs something that can serve as a content-bearers. I am going to call these things "times".[1] In this chapter I'll discuss one particular kind of entity that is suited to play this role; in the following chapter I consider other candidates. To tell us that things take place in a certain order, the temporal order needs temporal relations. On my view, whatever relations are best suited to order the temporal order are the temporal relations.

Temporal relations are of two varieties: quantitative and qualitative. *Is earlier than* is a qualitative temporal relation. A view of time can make do with qualitative relations, but there are cases in which we want temporal relations that are quantitative. That is, sometimes we want to know not only that x happened before y, but also that x happened seven minutes before y. Quantitative temporal relations require a metric. Mathematically, a metric is a function that maps pairs of points to numbers. For instance, given the set of real numbers ordered by $<$, $f(x, y) = |x - y|$

[1] One might also call these things "instants" to avoid the implication that times are a part of some entity called "Time". I think the worry here is misplaced. Times are a part of time. Trouble arises because "time" sends us "to seek for a corresponding substance" (Arthur Prior 1967, 17). The trick is to make sure we don't go seeking.

is a metric: f takes two members of $\mathbb{R}$ and yields another number, which we call the distance from x to y.[2] As we saw in the previous chapter, we can also use certain kinds of congruence relations as the temporal metric.[3] That is, we can say that x took twice as long as y; or we can say that x is three times as long before y as z is before w.[4] One might wonder why I have brought up the metric as something distinct from the temporal order. If the temporal order needs to have an ordering relation on times, then it might seem like we get a metric for free since it is "built into" the temporal order. I address this in S5.3.1.

The hard work ahead is showing how we get the temporal order and a metric within an Aristotelian framework. At the fundamental level there are substances that exercise causal powers. This ontological commitment does not give us much to start with, since it does not include times or temporal relations. In chapter three I discussed semantics for abstraction and gestured at semantics for construction. Here I put those semantics to work. I first take up the task of showing that times are abstractions from tensed claims, which just are a linguistic expression of the change that substances undergo. Building off of that, I offer a view of temporal relations to fill out the temporal order. I then argue that, while we can define a metric on our temporal order, whether a metric is a suitable *temporal* metric is a different matter.

---

[2] Not just any function is a metric. To be a metric, a function must also satisfy four further constraints, which are given at the beginning of S3.

[3] For instance, Skow (2010) takes "a temporal metric to be a relation like *x and y have the same temporal length*, or *the same amount of time passes during x as during y*—a two-place congruence relation on time intervals that (together with the betweenness relation on instants of time) satisfies some standard set of geometrical axioms, such as Hilbert's axioms for neutral geometry" (180). As stated, these congruence relations cannot be used to generate a mathematical metric. To get a mathematical metric from these relations, we need to satisfy the moderateness condition discussed in (Field 1984): we need to show how "magnitude relations between physical things and numbers" are "generated from relations among physical things alone" (45).

[4] This last option was suggested to me by Alexander Pruss.

5.2 *The Temporal Order*

As noted above, the temporal order requires both content—which we get from times—and an ordering of that content. We get both times and temporal relations from tensed statements.[5] I will briefly discuss the relation between changing substances, tense in natural language, and tense logic. From there I will go on to show how we can derive times and temporal relations.

5.2.1 *Tense and Tense Logic*

It's common to distinguish views of time based on whether they are a tensed theory or a tenseless theory. Views of the former kind are said to "take tense seriously", which is typically taken to mean that tense is an ineliminable aspect of reality. Tense is a property of verbs. Time and reality are not verbs, so it's unclear what it means to say that tense is an ineliminable aspect of reality. A slightly better interpretation of what tensed theories claim is that a description of reality in only tenseless terms would thereby be incomplete. But even if taking tense seriously is a thesis about how we describe reality, one still might wonder why we care about tense. What is tense supposed to tell us about reality?

The answer is that tense is the best way to describe change. The fundamental level of an Aristotelian metaphysic has substances with causal powers. I assume that some of these substances exercise their causal powers. To exercise causal powers is to bring about a change.[6] So, the fundamental level of my Aristotelian ontology has changing substances. We *talk* of change by talking about the gain and loss of

---

[5] This is quite similar to what Meyer (2013) calls tense primitivism, the thesis that "all temporal notions are to be analyzed in terms of conceptually primitive tense operators" (39). As long as we're clear that the primitivism is *conceptual*, this is not an inaccurate characterization of my view. On my view, the tense operators aren't metaphysically primitive: they are primitives in tense logic, but are metaphysically derivative. So, what I hold could be stated instead as: all temporal notions are to be analyzed in terms of the more basic tense operators.

[6] Just about every word in this sentence—"exercise", "causal powers", "bring about", and "change"—can be and has been subjected to philosophical scrutiny. Do your best to ignore that scrutiny here; I'm painting in broad strokes at the moment.

properties. In a natural language like English, there are two ways to express this kind of difference. One might use verb tense: "The plants *were* doing well, but now they *are* not." Or one might appeal to temporal indices: "In 2013, the plants are doing well; in 2014, the plants are not doing well." The relationalist holds that temporal locations are not fundamental. If we take language to reflect ontology, then the relationalist will say that language that requires temporal locations to express change does not reflect what is fundamental as accurately as language that does not require temporal locations. So, the relationalist will say that "The plants were doing well, but now they're not" more accurately reflects the fundamental ontology than "In 2013, the plants are doing well; in 2014, the plants are not doing well". Insofar as we're looking for a language of fundamentality—i.e. a language that most accurately reflects what is fundamental and what the fundamental is like—tensed language is the way to go.

Natural languages that are tensed (such as English) can be used to tell us about how substances change. Natural languages are also messy: they don't codify truths about tense. If a language for the fundamental is supposed to use tense to tell us about change, then it is desirable if that language has a systematic way to express what tense tells us about change. While English does not offer such a systematic approach to tense, one might try to offer a systematic theory of verb tense. Indeed, in 1941 J.N. Findlay claimed that "our conventions with regard to tenses are so well worked out that we have practically the materials in them for a formal calculus" (Findlay 1941, 233). Several years later A.N. Prior offered such a formal calculus, giving us the first system of tense logic. It turns out that tense logic cannot serve as an adequate theory of verb tense for natural languages (Meyer 2015). But that does not thereby rule out tense logic as a language for the fundamental; we are interested in a tensed language because it is a more accurate representation of change than is a language that appeals to temporal locations. As long as the resulting view of time can express tensed truths in English, it doesn't matter if some English sentences cannot be translated into simple tense-logic formulas. Moreover, of the formal languages available to us, tense logic is the best option for expressing the truths about change. The closest competitor is First-Order Logic (FOL). But in order to adequately account for change, FOL would need to add an extra argument in each predicate for a temporal index. If this modified version of FOL is the language for the fundamental, that would suggest that temporal indices are fundamental.[7] So, if nothing else, tense logic is our best bet for codifying truths about how things change. Thus, if we're careful, we can use tense logic to inform us about the structure of time, since time depends on changing substances, and our axioms for tense logic tell us something about how substances change. A few words about tense logic are in order since I will use tense logic to derive times and temporal relations.

Tense logic is an intensional logic. We start with a background logic and introduce two operators, P and F (read as "It was the case that ..." and "It will be the case that ...", respectively). For two reasons, I will use sentential logic as the background logic. First, it's easier to present tense logic when sentential logic is the background logic. For instance, predicate logic complicates the picture since we also need rules for quantifiers. For present purposes the expressive power we gain with predicate logic is not worth the extra complications that it brings with it. Second, using sentences allows me to sidestep questions about the nature of propositions. Specifically, I can avoid questions about whether propositions can

[7] One could modify FOL in another way: the predicates are tensed. Rather than "IsOrange(x, t)", we would have three predicates: "WasOrange(x)", "IsOrange(x)", and "WillBeOrange(x)". If these predicates are related, it's hard to see how the resulting logic is not just tense logic in disguise. On the other hand, it seems to be a real cost to say that such predicates unrelated since they clearly seem related.

change their truth-values and questions about whether propositions such as ⟨Socrates is sitting⟩ are complete.[8]

The stock of sentences our tense logic employs does not have sentences that refer to times. For instance, "Socrates is sitting," "Dan is typing," and "Smaug is a dragon" are all sentences our tense logic can employ; but "At t, Smaug is breathing fire" and "I turn 27 in 2015" are not in our stock of sentences. That said, a theory of time must be able to give a tenseless description of reality in order to meet some of the desiderata discussed in the previous chapter. So, one goal is to derive statements that have temporal indices (e.g. "At t, Smaug is breathing fire") from tensed statements ("Smaug is breathing fire") since time-indexed sentences afford us a tenseless description of the world.

Above I said that P and F are sentential operators. In what follows, formulas will be represented by italicized, lower-case Roman letters. Variables for formulas will be represented by Greek letters. Whenever a formula is not in the scope of a tense operator, it is translated as a present-tense English sentence, and for that reason I will call it a "present-tense formula". So, "s" might translate "Socrates is sitting", but it cannot be a translation of "Socrates was sitting". The latter would be translated "Ps". In general, where ϕ is any tense-logic formula, "$P\phi$" means "it was the case that ϕ" and "$F\phi$" means "it will be the case that ϕ." Using negation, we can define two further operators, "H" and "G". "$H\phi$" expresses the claim "it has always been the case that ϕ"; it is defined as $\neg P \neg \phi$. "$G\phi$" expresses the claim "it will always be the case that ϕ"; it is defined as $\neg F \neg \phi$.

The axioms that govern the use of "F" and "P" tell us what the structure of time is. K_t is a minimal tense logic, which, in addition to the axioms and rules of sentential logic, consists of the following four axiom schemata (two of which, A2

[8] See (Arthur Prior 1967, 15–17) and (P. T. Geach 1949, 1955) about propositions being complete. For recent defenses of this view see (Perl 2015) and (Sullivan 2014).

and A4, are mirror images of the others, A1 and A3, respectively) and two inference rules, RH and RG:

A1:	$\phi \to HF\phi$	A2:	$\phi \to GP\phi$
A3:	$H(\phi \to \psi) \to (H\phi \to H\psi)$	A4:	$G(\phi \to \psi) \to (G\phi \to G\psi)$
RH:	If $\vdash \phi$, then $\vdash H\phi$	RG:	If $\vdash \phi$, then $\vdash G\phi$

K_t does not attribute much structure to time. Contemporary physics and the folk theory may demand more structure than is offered by K_t. If that's the case, then we can supplement K_t to account for the additional structure. Here are some common additions to K_t and what they tell us about the structure of time:

Denseness	$F\phi \to FF\phi$ or $P\phi \to PP\phi$
Transitivity	$FF\phi \to F\phi$ or $PP\phi \to P\phi$
Linear Past	$FP\phi \to (P\phi \vee (\phi \vee F\phi))$
Comparability	$(P\phi \wedge P\psi) \to (P(\phi \wedge \psi) \vee P(\phi \wedge P\psi) \vee P(P\phi \vee \psi))$ or
	$(F\phi \wedge F\psi) \to (F(\phi \wedge \psi) \vee F(\phi \wedge F\psi) \vee F(F\phi \vee \psi))$

For axioms such as denseness, transitivity, and comparability, if one endorses one version of the axiom, one often endorses the mirror image as well, since mirror images are not, in general, equivalent. But in other cases, such as Linear Past, one may endorse the axiom without also embracing its mirror image, which in this case would guarantee a linear future. These properties can be expressed in the model-theoretic semantics that I will discuss below.[9]

Tense logic offers a formal way of talking about changing substances. Using the resources of tense logic, I'll now show how one can derive times and temporal relations. Since times and temporal relations are the only components of the temporal order, deriving both of these is sufficient for deriving the temporal order.

[9] For more axioms that one can introduce to reflect the structure of time see (Goranko and Galton 2015) and (Meyer 2015). There are some properties, such as irreflexivity, that cannot be expressed using tense logic formulas. See (Van Benthem 1983).

5.2.2 Times

Times are the content-bearers for the temporal order. Their primary role is to tell us what is taking place. As I will argue in the next chapter, one cannot have a strong connection between time and objects if times are fundamental. Since relationalism entails a strong connection between time and objects—time depends for its existence on changing substances—the relationalist must derive times from changing substances.

The only requirements on a view of times is that times provide content for the temporal order and that times can be ordered. This leaves the relationalist with several options for what times are. Crisp (2007) and Bourne (2006) hold that times are sentences (or propositions) of a certain sort. Markosian (2004) and Meyer (2013), on the other hand, believe that times are like possible worlds (which, depending on one's view of possible worlds, may be the same as the previous view). These two kinds of views seem to be the most common. But other candidates have been proposed as well. Russell (1936) and Whitehead (1919) suggested that times are constructed from events; Zalta (1987) defines and employs situations; and Chisholm (1979) uses Chisholmian states of affairs. This is by no means exhaustive.[10] In the next chapter I will argue that some of these views are less attractive than others.

Here I want to focus on a view of times suggested by Arthur Prior (1967). Prior says that times are *world states*. A world state is a sentence typetype of sentence. Specifically, a world-state "is a present truth from which everything that is now true permanently follows" (79). To say that a sentence q permanently follows from world-state p is to say that

---

[10] Both in terms of similar views of times and different kinds of views. (Prior and Fine 1977), (Davidson 2003, 2004), (Padgett and Byerly 2014), and (Rasmussen 2015) all offer other views that are of apiece with the ones mentioned in the text. See also Van Cleve's interpretation of Prior in (Van Cleve 2011a). In the next chapter I will consider views of times that are not so similar to the ones mentioned in the text.

> if p expresses the total present world-state, and q is now true, then although both p and q may be false at other times (and also p may be false and q still true), the relation between them is such—p so *contains* q—that the implication of q by p will be true even at those other times, in fact at all times, however the world changes. (Arthur Prior 1967, 79)

Using this, Prior offers the following definition of a world state:

WS: ϕ is a world state iff $\phi \wedge \forall\psi(\psi \rightarrow A(\phi \rightarrow \psi))$ (79),[11]

where "$A\phi$" ("It is always the case that ϕ") is defined as $H\phi \wedge (\phi \wedge G\phi)$. I want to make three remarks about WS. First, it's unclear whether Prior intends ϕ to be restricted in any way. In some places Prior uses Greek letters as variables for formulas and lower-case Roman letters for atomic sentences, but in others it looks like he uses lower-case Roman letters as variables. As stated, world states are not limited to present-tense sentences since ϕ is a variable for any formula; i.e., a formula such as "Pp" could be a world state if it meets both criteria in WS. But what Prior actually writes is that a world state is a formula p such that "$p \wedge \forall q(q \rightarrow L(p \rightarrow q))$, where $L\alpha = \alpha \wedge (H\alpha \wedge G\alpha)$, or if you like $L = GH$" (79).[12] This leaves open the possibility that only present-tense, atomic formulas are candidates for world states—and world states are only required to permanently imply other present-tense, atomic formulas, which would be odd since world states are supposed to permanently imply *every* other present truth (which, presumably, will include some truths about the

[11] If quantifying over sentences is not appealing, Prior offers a way to introduce world-state sentences without the quantifiers. To do this, we take $W\phi$ (read as "ϕ is a world state") as a primitive and add the following two axioms:
W1: $W\phi \rightarrow \phi$
W2: $W\phi \rightarrow (\psi \rightarrow A(\phi \rightarrow \psi))$.
But provided that sentences (or propositions) are among the derivative entities, quantifying over sentences should not be problematic: one could simply substitute the universal quantifier in the text with the $\mathcal{K}$-universal quantifier discussed in chapter three, if sentences (propositions) are abstracted from substances. In the text I will use the ordinary quantifiers, since they make for a cleaner presentation of the views in question. But, in order to reduce ontological cost, $\mathcal{K}$-quantifiers (or whatever quantifiers are needed for construction) are to be used when they can.

[12] This is a translation from the Polish notation that Prior used. Here's the Polish notation: $Kp\Pi qCqLCpq$, where $L\alpha = KK\alpha H\alpha G\alpha$, or if you like $L = GH$.

past and the future). But the real problem with this option is that it's difficult to think of an atomic truth that implies all other (atomic) truths; so, this appears to be a non-starter.[13] So, leaving ϕ and ψ unrestricted is the better way to interpret WS. Second, even if world states are not limited to present-tense formulas, it is only formulas that are presently true that are candidates for world states. In other words, there are no past or future world states; at best we can say that some formula was a world state or will be a world, but there is no non-present truth that is a world state. Third, WS is consistent with a fixed future. This is desirable since whether the future is fixed seems to be a claim about the structure of time, and truths about the structure of time are best handled by modifying the axioms of our tense logic.

In light of the second remark, we might modify Prior's definition of a world state. Specifically, we might want to say that a world state is any formula such that, when it's true, it permanently implies everything else that is then true. For simplicity, I'll say that "$S\alpha$" ("It is sometimes the case that α") means $P\alpha \vee \alpha \vee F\alpha$. We then have:

WS*: ϕ is a world state iff $S\phi \wedge \forall\psi[S(\phi \wedge \psi) \rightarrow A(\phi \rightarrow \psi)]$.

The first conjunct captures the idea that, as long as it's true at some point, a sentence is a candidate for a world state; the second conjunct expresses the claim that if ϕ and ψ are ever both true, then it is always true that ϕ implies ψ, which is another way of expressing permanent implication. WS* might seem superior to WS because the former yields more formulas that are (now) world states, and we will need world states to talk about the past and the future. However, when I talk about world-state systems below, it will turn out that both definitions allow us to refer to past and future world states, making the alleged advantage merely illusory. But it is slightly

[13] Though one could try to run with the opening proposition of Wittgenstein's *Tractatus*: The world is everything that is the case. (Prior notes that Meredith and Prior (1965) explore this possibility for modality by introducing a constant n with the following three axioms: (i) n ("The world is the case"), (ii) $p \rightarrow \Box(n \rightarrow p)$ ("The world is everything that is the case"); and (iii) $\Box n \rightarrow p$ ("The world is not necessary").)

more convenient to formulate the truth conditions for an ordering relation on world states using WS* as our definition of a world state, so I will make that the official definition.

What is important about world states is that if p is a world state, "then whatever q may be, either p permanently implies q or p permanently implies not q" (Arthur Prior 1967, 80).[14] This means that world states are *maximal*: they leave no sentence unaccounted for. And if no sentence is unaccounted for, then world states tell us everything that can be told about what is happening. So, world states are a suitable candidate for times.

The kind of maximality that we can prove is what you might call "implication maximality": world states tell us everything about the world by permanently implying everything that is then true about the world. But this is not the only option for maximality: we can attempt to make world-states maximal by making world states themselves "contain", rather than imply, every other sentence.

One promising option is to endorse something like the Big Conjunctive Fact (BCF) discussed in Gale and Pruss (1999). A BCF is a "maximal, compossible conjunction", where a sentence is maximal just in case, for every sentence p, "either p is a conjunct in this conjunction or its negation, not-p, is, and it is compossible in that it is conceptually or logically possible that all of the conjuncts be true together" (461–62). Davey and Clifton (2001) argue that there is no BCF, because there is no Big Conjunctive Contingent Fact (BCCF)—a maximal conjunction of contingent propositions—though they note that a restricted version of BCCF is not

[14] Prior claims the simplest way to show this is to endorse a tense logic that yields the tense-logic analog of the modal logic S5. We do not want that strong of a tense logic, for it means that the earlier-than and later-than relations are reflexive, which is clearly not the case for times. It turns out, though, that there is a less controversial way to prove the same conclusion. There is a slight difference in the proof depending on whether we use WS or WS* as our definition of the world state, but here's a sketch of the proof. Suppose "p" denotes a world state and "q" denotes any other sentence. Whenever "p" is true, either "q" or "$\neg q$" is also true. Suppose "p" is true. If "q" is true, then "$A(p \to q)$" is; if "$\neg q$" is true, then so is "$A(p \to \neg q)$". So, $A(p \to q) \vee A(p \to \neg q)$. Therefore, whenever "$p$" is true, either "$p$" permanently implies "$q$" or it permanently implies "$\neg q$".

ruled out.[15] In their reply to Davey and Clifton, Gale and Pruss (2002) suggest what this restricted version of BCCF might look like, noting that the details will depend on ontological issues. For instance, if your ontology has true atomic propositions in it, you could endorse a conjunction comprised of:

> (a) all true contingent atomic propositions;
> (b) a "that's all clause" that says that any true contingent atomic proposition is one of these ones; (this clause will involve an infinite disjunction such as in: "for all p, if p is a true contingent atomic proposition then p is a_1 or a_2 or ...");
> (c) all true propositions appearing in the *explananda* of basic propositions or of conjunctions thereof;
> (d) all true basic propositions reporting causal relations;
> (e) a "that's all clause" that says that all the actual explanatory relations supervene on the facts reported in the above conjuncts (95).

If, as I suggested in chapter three, the Aristotelian can derive propositions from substances, then this is an attractive option since propositions will be of no ontological cost. Before moving on, though, I want to show how this kind of a view is at home in an Aristotelian ontology by suggesting a slight variant.

In chapter three I stated that there are fundamental entities (in this case, substances) that change. It seems uncontroversial to say that there are sentences that report these changes.[16] (And since substances have causal powers, among these reports will be reports about causal relations between substances.) Fundamental entities ground non-fundamental entities. If there are reports about fundamental entities, then surely there are reports about the grounded, non-fundamental entities too. We also have grounding relations—"x is an abstraction from y" and "y is

[15] Recently, Christopher M. P. Tomaszewski (2016) has argued for a similar conclusion, that there is no conjunction of all contingently true propositions, by appealing to by appealing to Cantor's theorem.

[16] What is controversial is whether we get these reports for free. In chapter three I mentioned that there is hope that we can derive propositions via abstraction (or construction). It's plausible that we can derive reports (which, I assume, are just a certain variety of proposition) directly from substances, in which case they are of no ontological cost. In the worst-case scenario, we need to take reports as fundamental entities as well.

constructed from the xs"—which means that there are truths about what grounds what. And this is all we need to get something like a BCCF: take the conjunction of all (non-logically-redundant) reports and truths about what grounds what, where two reports are logically redundant iff one report is logically equivalent to the other. (For instance, "p" and "$p \vee p$" are logically redundant.) This yields something similar to the restricted version of BCCF proposed in Gale and Pruss (2002).

We now have two options to make world states maximal, though "maximal" means something different on each option. Option one says that maximality is a matter of implication: world states are maximal because they permanently imply every sentence or its negation. A mark in favor of this option is that we need not worry about whether there are maximal sentences. Option two attempts to construct sentences that are maximal. Rather than just have sentences that permanently imply every other sentence or its negation, this option says that a world state is a sentence of which every other sentence or its negation is a conjunct. This offers a stronger sense of "maximal", though we must defend the existence of such maximal sentences and then modify the definition of a world state so that such maximal sentences are the only candidates for a world state. As long as one of these options is viable, we can say that world states are maximal. But even if neither option works, the view that times are world states is not refuted. Most of what follows still works even if world states are not maximal: I simply need some other kind of (ontologically innocent) entity to get the content for the temporal order so that I do not need to appeal to eternalism. So, in the grand scheme of things, the issue of how much content world states have is a relatively minor one.

Using maximal world states as times might seem to violate the Folk Theoretic claim that the future is open.[17] That a maximal world state permanently implies either q or its negation, whatever q may be, means that world states imply other

[17] This is a modified version of a worry that Prior raises in (Arthur Prior 1967, 82).

world states.[18] If w_1 is a world state, then there is some world state w_2 such that w_1 permanently implies Fw_2. But then there is also a world state w_3 such that w_2 permanently implies Fw_3. And now it starts to look like the future is determined rather than open.

Prior points out that such an argument does not rule out the possibility of an open future, for a tense logic that does not have a future-directed linearity axiom (i.e. a tense logic on which time "branches") still accepts arguments like the one in the previous paragraph. But, in a tense logic on which time branches, Fw_2 asserts not that w_2 will, with certainty, be a future world state but only that w_2 will be a world state, which comes closer to saying that w_2 could be a world state (Arthur Prior 1967, 82).[19] In other words, the future tense operator is weaker so that even if world state w_1 permanently entails Fw_2, w_1 will also permanently imply, for some world state w_4 incompatible with w_2, Fw_4. So, for now, we can push aside worries about the openness of the future until we discuss how well my view handles the Folk Theory of Time.

5.2.3 Time and Temporal Relations

The temporal order requires not only content but also an order to that content. A standard approach is to order times with a relation such as *is earlier than.*[20] To define this relation, we can avail ourselves of Prior's notion of permanent implication.

---

[18] As we'll see in the next chapter, Crisp (2007) has a view of times on which this is also true; Bourne (2006), on the other hand, is careful to exclude one time from implying another.

[19] Prior brings up the distinction between the two sense of "will" in (Arthur Prior 1967, ch. vii) and (A.N. Prior 1968/2003, ch. iv).

[20] Van Fraassen (1970) suggests that the relation of pair separation—(a, c) separates (b, d)—should be the basic temporal ordering relation. He is worried that if the earlier-than relation has its usual properties (irreflexivity, asymmetry, and transitivity), then we must deny the possibility of circular eternal recurrence. I stick with the standard approach in the text. For the relationalist, the basic temporal ordering relation is derived from the axioms that govern the tense operators, which, in turn, depend on what's true at the fundamental level. So, if the resulting temporal ordering relation is the usual earlier-than relation, it's not a problem to deny circular eternal recurrence because the thesis of circular eternal recurrence is false.

If times are world states, then one time is earlier than another provided that we have two world states that are never both true and the earlier permanently implies the later. Formally, we can express this as: where p and q are distinct world states, p is earlier than q iff $\neg S(p \wedge q) \wedge A(p \rightarrow Fq)$. Likewise for *is later than*: for world states p and q, p is later than q iff $\neg S(p \wedge q) \wedge A(q \rightarrow Fp)$.[21] This does not offer much about the nature of the ordering relation: it is consistent with branching time and linear time, as well as circular time (the definition for *is earlier than* does not rule out cases where $A(p \rightarrow Fq)$ and $A(q \rightarrow Fp)$). To say more precisely what the ordering relation is, we need to determine which axioms we can add to K_t. For instance, the ordering relation is the familiar *is earlier than* if we can add both past- and future-directed linearity axioms.

The taxonomy of views I presented in chapter two used reductionism about the direction of time as one way to partition logical space. It's worth noting here that this view endorses reductionism about the direction of time. Temporal relations such as *is earlier than* describe the direction of time; but these relations are reducible to tensed statements, which, in turn, are reducible to the changes that substances undergo. We can say that the direction of time is "built into" the tense operators, which suggests that the tense operators take the direction of time as primitive. But the behavior of the tense operators is parasitic on the way substances change. The direction of time is "built into" the tense operators because of the ways in which substances change. So, the direction of time is reducible to the ways in which substances change.[22]

---

[21] We can also use P: e.g., p is earlier than q iff $\neg S(p \wedge q) \wedge A(q \rightarrow Pp)$.

[22] Perhaps you think this isn't really reductionism about the direction of time since the P and F operators still embody the direction of time: all that I've done, you might think, is reduce the vocabulary, and there's more to a reduction than reducing the vocabulary. (Thanks to Alexander Pruss for pushing this point. For similar remarks see (Fine 2013, 4).) I suspect that there is a verbal dispute over "reduction" here. Recall from chapter two that reductionism about the direction of time amounts to explaining why time "goes" this way rather than that. While the P and F operators embody the direction of time, they do so by reporting truths about change.

Defining temporal relations in terms of tense operators has a nice consequence: it is easy to be consistent with the claim that simultaneity is relative (thus satisfying part of the requirement that our view of time is consistent with our best physics). To show this requires making a few remarks about events and then defining the simultaneity relation.

5.2.4 World States and Events

The relata of the simultaneity relation are events. Events are reported by sentences, which are expressed in tense logic by formulas. We can use tense logic and world states to define a number of relations on events. As noted above, though, there will be some expressive limitations due to the fact that tense logic is not an adequate theory of English verb tense; these limitations will be lifted once we have "at-t" locutions at our disposal. The aim here is to show how we can extend ordering on the temporal order to things other than world state. To accomplish that goal, I need not go too far below the surface.

One basic desideratum for talking about events is being able to say that events occur, or happen. We can express this by talking about world states permanently implying event reports. In what follows, capital letters (e.g., E) will name events and italicized capital letters (e.g., E) will name reports of events. An event report is present-tense when there is no tense operator that takes wide scope. In keeping with the spirit of the project, it is tempting to talk about events that have occurred, are occurring, or will occur. In practice, it will be easier to define a "tenseless" sense of "occurs":

While the P and F operators are the more basic temporal notions (to use terms from an earlier footnote), they are *not* basic. The axioms governing P and F report the way time "goes" because of the ways substances change. That seems to fit the criterion given in chapter two, though one might argue my view results in what you could call "explanationism" about the direction of time rather than reductionism.

Occurs: E occurs at t iff t is a world state and t permanently implies E.[23]

Given this, we can say that E is instantaneous iff there is exactly one time (world state) at which E occurs. Provided that there are at least two distinct times at which E occurs, E is temporally extended.[24] And there are a number of other relations that we can define. Letting p and q be variables for world states, we have:

- E_1 and E_2 are wholly simultaneous iff for any p, E_1 occurs at p iff E_2 does, and there is some q at which E_1 occurs.
- E_1 and E_2 are partly simultaneous iff there is some p at which E_1 and E_2 both occur, and E_1 and E_2 are not wholly simultaneous.
- E_1 and E_2 are not simultaneous iff there is no p at which E_1 and E_2 both occur.

---

[23] For those curious, here's how one could proceed in a manner that appeals to tensed notions:

OccurN: Event E is occurring iff E;

OccurP: Event E has occurred iff PE;

OccurF: Event E will occur iff FE.

Note that if "E" is true, then there is some world state that permanently implies E, since world states permanently imply every truth or its negation. Depending on other metaphysical commitments, how we express that claim will vary. For instance, the right hand side of OccurN is equivalent to $\exists\phi(W(\phi) \wedge \phi \wedge A(\phi \rightarrow E))$ but can be simplified to $\exists\phi(W(\phi) \wedge A(\phi \rightarrow E))$ if we endorse WS instead of WS* as our definition of a world state. Given WS, we have two options for OccurP: $\exists\phi(PW(\phi) \wedge P\phi \wedge A(\phi \rightarrow E))$ or as $P\exists\phi(W(\phi) \wedge A(\phi \rightarrow E))$, the latter of which seems more presentist-friendly. (One could adopt this given WS*. But whether this is more presentist-friendly will depend on some messy issues in quantified tense logic, among which are one's (perhaps forced) commitment to the tense-logic versions of the Barcan Formula: $P\exists x\phi \rightarrow \exists xP\phi$ and $F\exists x\phi \rightarrow \exists xF\phi$.)

[24] Again, for those curious, we could instead build off of the following:

Wholly Present: E is wholly present iff E is occurring but never did and never will occur (more perspicuously: E is occurring, it has always been the case that E is not occurring, and it will always be the case that E is not occurring).

Wholly Past: E is wholly past iff E occurred, is not occurring, and never will occur.

Wholly Future: E is wholly future iff E will occur, is not occurring, and never did occur.

Another way of saying that E is wholly present is to say that E is instantaneous. We can then say that E was instantaneous provided that E was wholly present, and E will be instantaneous provide that it will be wholly present. And provided that E is never instantaneous but did occur, is occuring, or will occur (i.e. it's not the case that E was, is, or will be instantaneous but does occur at some point), we can say that E is temporally extended. Alternatively, one could say that E is extended just in case E is occuring and did occur, is occuring and will occur, or did occur and will occur.

- E_1 is wholly earlier than E_2 iff for any p and q, if E_1 occurs at p and E_2 occurs at q, then p is earlier than q, and there is some r at which E_1 occurs and some s at which E_2 occurs (i.e. any world state at which E_1 occurs is earlier than a world state at which E_2 occurs).
- E_1 is wholly later than E_2 iff for any p and q, if E_1 occurs at p and E_2 occurs at q, then p is later than q, and there is some r at which E_1 occurs and some s at which E_2 occurs.
- E_1 is partly earlier than E_2 iff E_1 and E_2 are partly simultaneous, and there is some p at which E_1 occurs and, for any other q, if E_2 occurs at q, then q is later than p.
- E_1 is partly later than E_2 iff E_1 and E_2 are partly simultaneous, and there is some p at which E_1 occurs and, for any other q, if E_2 occurs at q, then q is earlier than p.

(Note that, as long as another view of times can give truth conditions for "E occurs at t", the preceding definitions will work on that view.)

5.2.5 The Relativity of Simultaneity

According to relativity theory, simultaneity is relative. Einstein (1920) gives the following example to illustrate the point. Suppose a train is moving along the rails with a constant velocity, and one of the cars is struck by two bolts of lightning. Bolt 1 strikes the front of the car, Bolt 2 strikes the back. We can imagine someone on the railway embankment watching the train go by. According to this observer, the two lightning bolts strike the train simultaneously (i.e. "Bolt 1 strikes the front of the car" and "Bolt two strikes the back of the car" are permanently implied by the same world state). But according to a passenger sitting in the middle of the car that is struck, Bolt 1 hits the car before Bolt 2 (i.e. "Bolt 1 strikes the front of the car" is permanently implied by some world state p and "Bolt two strikes the back of the car" is permanently implied by some distinct world state q and p is earlier than q).

What the thought experiment shows us is that we need a way of saying that events A and B are simultaneous in one reference frame, but A occurs before B in another reference frame. We can do this in two steps with world states. In step one we'll use world states to construct classes of reference frames; in step two we'll account for the relativity of simultaneity with those the classes of reference frames.

Step one. In relativity theory, for any two events that are spacelike separated, there is a reference frame in which those events are simultaneous. This suggests that reference frames are like times. On the view that I am developing, world states play the role of times, so it is natural to see if world states can play the role of reference frames as well. A reference frame can be used to partition spacetime into spacelike hypersurfaces; the resulting class of reference frames is, in effect, a temporal order. We can mimic this with world states by talking about a world-state system. A world-state system will be a certain kind of set of world states, and we can prove that such a set exists.

We'll start with an equivalence relation on world states:

WS Equiv: For any world states ϕ and ψ, $\phi \sim \psi$ iff $A(\phi \to \psi) \wedge A(\psi \to \phi)$.

WS Equiv says that two world states are equivalent just in case they permanently imply one another. This means that they don't disagree on what is presently true when they are the present world states.[25] Using equivalence classes of world states to construct world-state systems cuts out redundant world-state systems—two world-

[25] Let p and q be equivalent world states that disagree about what is presently true. Then there is some formula α such that $A(p \to \alpha)$ and $A(q \to \neg\alpha)$, which implies $p \to \alpha$ and $q \to \neg\alpha$. But since p and q are equivalent, whenever p is true, so q. But then we have α and $\neg\alpha$.

state systems that "say the same thing" with respect to what goes on when. It is not difficult to show that $p \sim q$ is an equivalence relation.[26]

And now for the proof of the existence of a world-state system. Say that a partial world-state system is any set of equivalence classes of world states totally ordered by the earlier-than relation.[27] (Note that partial-world state systems contain at most one world state from each equivalence class of world states since a partial world-state system is totally ordered by the earlier-than relation: every world state in the partial system must be earlier than or later than every other member of the system.) Let S be the set of all partial world-state systems, ordered by $\subseteq$. S is a partially ordered set. Now consider some subset T of S, where T is totally ordered by $\subseteq$.[28] Now let U be the union of partial world-state systems that are members of T. U is an upper bound for T: every member of T is a subset of U. Moreover, U is a member of S.[29] So, every totally-ordered subset of S has an upper bound.

---

[26] Proof. Showing reflexivity is trivial: p permanently implies itself. Symmetry is also trivial: if $A(p \to q) \wedge A(q \to p)$, then $A(q \to p) \wedge A(p \to q)$. Transitivity is more involved. Assume $p \sim q$ and $q \sim r$. We then have (i) $A(p \to q)$ and $A(q \to r)$ as well as (ii) $A(r \to q)$ and $A(q \to p)$. Consider the first pair, (i). Recall that $A\phi = H\phi \wedge (\phi \wedge F\phi)$. So we have $H(p \to q) \wedge ((p \to q) \wedge F(p \to q))$ and $H(q \to r) \wedge ((q \to r) \wedge F(q \to r))$. It is trivial to show $p \to r$. To show $H(p \to r)$ and $G(p \to r)$, we employ RH and RG. For $H(p \to r)$, this is accomplished formally by a subproof rule that, within the subproof, allows us to discharge H from both $H(p \to q)$ and $H(q \to r)$, leaving us with $p \to r$ and $q \to r$, from which $p \to r$ follows. We then close the subproof and conclude $H(p \to r)$. The proof for $G(p \to r)$ is the mirror image of this. (The subproof rules for H intro and G intro are adapted from a necessity introduction subproof rule for modal logic (see (Konyndyk 1986, 34)).) Now we have $H(p \to r) \wedge ((p \to r) \wedge G(p \to r))$ which is equivalent to $A(p \to r)$. The proof for the second pair, (ii), is analogous to that for (i). Therefore, $p \sim r$.

[27] And here is where the difference between WS and WS* comes up for the final time. Given WS*, a partial world-state system is as stated in the text. For WS, on the other hand, a partial world-state system is any set of formulas such that each formula was, is, or will be a world state, and these formulas are ordered by the earlier-than relation.

[28] This means that T is any ordered subset of S whose members are comparable, i.e. for any members a and b of T, $a \subseteq b$ or $b \subseteq a$.

[29] Let a and b be members of U. Then there is some $P_a \in T$ such that $a \in P_a$, and there is some $P_b \in T$ such that $b \in P_b$. T is totally ordered, so $P_a \subseteq P_b$, or $P_b \subseteq P_a$. If $P_a \subseteq P_b$, then a is also in P_b, which means that a and b are ordered by the earlier-than relation. So, the members of U are ordered by the same relation. The same reasoning applies if $P_b \subseteq P_a$. So, the members of U are ordered by the earlier-than relation, and hence U is a partial world-state system and therefore a member of S.

Then, by Zorn's lemma, S has a maximal element: there is some $P_M \in S$ such that, for every $P \in S$, if $P_M \subseteq P$, then $P_M = P$. We then say that P_M is a (maximal) world-state system. Note that P_M is a set of world states that is totally ordered by the earlier-than relation. Moreover, as mentioned above, P_M contains at most one world state from each equivalence class of world states.

Step two. To account for the relativity of simultaneity we need two events A and B such that A and B are (wholly) simultaneous according to one world-state system but not according to another. If there are two non-equivalent world-state systems W and W' such that A and B occur in each system, then we will have the desired result. Suppose A is Bolt 1 striking the car and B is Bolt 2 striking the car. For simplicity, assume that striking is instantaneous. Then an event report for A is A; likewise, B is a report of B. From the above, we know that A occurs iff some world state permanently implies A, and B occurs iff some world state permanently implies B. If there is some world-state system on which some world state permanently implies both A and B, then A and B are simultaneous. On the other hand, Bolt 1 strikes the car before Bolt 2 iff there is a world state permanently implies A and a later world state that permanently implies B. If there is some world-state system according to which this is the case, then we have the desired result: whether Bolt 1 strikes the car before Bolt 2 depends on one's reference frame.

The big question is: Why think that there are two such world-state systems? An affirmative answer depends on the claim that event reports need not be unique. In the previous paragraph I deliberately left unspecified what formula reports each of our two events. If simultaneity really is relative, we should not expect that there is a (unique) report of the event until we have specified a reference frame—that's just what the relativity of simultaneity says! Einstein's thought experiment offers two ways of reporting Bolt 1 and Bolt 2 striking the car. According to one report, "Bolt 1 strikes the car" is the correct report of A while "Bolt 2 strikes the car" is the correct report of B.[30] According to a second report "Bolt 1 struck the car" is the correct report of A while "Bolt 2 strikes the car" is the correct report of B.[31] So, one report says "$a \wedge b$" while the other says "$Pa \wedge b$". Let's call these R_1 and R_2, respectively. As long as there is no global inconsistency in either report—i.e., as long as one report does not lead to a contradiction when reporting other events (once we adjust the other reports accordingly)—there's really no reason to reject the report. In other words, there no reason to reject the claim that some world state p permanently implies R_1 while some other world state q permanently implies R_2.

And now we can show that my view is consistent with the relativity of simultaneity. If some world state p permanently implies R_1 while some other world state q permanently implies R_2, we should say that p and q are not comparable. If p and q are not comparable, then there will be partial world-state systems that are not comparable: any partial world-state system that contains p cannot contain q and vice versa, since partial world-state systems are totally ordered. Since p and q are world states, there is some partial system that contains p and another that contains q. But now consider totally-ordered sets of partial world-state systems such that p is a member of one such system. Using similar reasoning from Step One, we can conclude that there is a maximal partial world-state system, P_p. And by repeating the reasoning for partial world-state systems that contain q, we have another maximal system P_q. But P_p and P_q will not be comparable. And since p and q are not identical, p is not a member of P_q, and q is not a member of P_p. So, we have distinct world-state systems. Finally, we need to relativize the relations on events to world

30 Or"Bolt 1 struck the car" and "Bolt 2 struck the car"; or "Bolt 1 will strike the car" and "Bolt 2 will strike the car". All we need is that one world state permanently entails both sentences.

31 Again, you can alter which tense operators you use as long as the relation between the sentences stays the same. This is another kind of non-uniqueness of event reports, but it's not a very interesting kind.

states within a world-state system. (One way to do this is restrict the quantifiers that appear in the above definitions.) And that gets us the relativity of simultaneity.

Before moving on, I want to comment on an alleged ontological commitment of the relativity of simultaneity: eternalism about objects. According to the relativity of simultaneity, there is no privileged reference frame; i.e. there is no reference frame that correctly picks out all of the temporal relations between events while other reference frames do not. Now, it seems uncontroversial to say that everything present is real.[32] Moreover, anything simultaneous with something present is also present. In particular, consider my present state. If simultaneity is relative, then for any event that is spacelike separated from my present state (i.e. in the complement of my light cone), there is a reference frame in which that event is simultaneous to my present state. So, every event that is spacelike separated from me is real. But now consider some event S that is spacelike separated from me. By the same reasoning, every event that is spacelike separated from S is real. But there will be some events that are spacelike separated for me, yet are not spacelike separated for S. This means that some events that are absolutely future or past for S are real. And it seems likely that we can extend this argument to arrive at the conclusion that all future events are real. If this is a consequence of the relativity of simultaneity, it spells trouble, for in chapter two I argued that one need not take a stance on eternalism about objects in order to have a complete view of time.

Here are two ways to respond to this worry. First, one could follow Tooley (1997) and Craig (2000b) and question whether simultaneity really is relative: perhaps there is a metaphysically privileged reference frame such that only some events that are spacelike separated from me are really simultaneous with me, and therefore present; all the others are simultaneous only in some less real sense. Given what I've said about world states, this would amount to saying that, even though there

[32] The following argument was suggested to me by Alexander Pruss.

are multiple world-state systems, each of which imply that certain relations hold between events, there is only one system that correctly describes the relations that hold between events. (We could even say that this is the only world-state system on which it is really the case that every world state was, is, or will be true.) A second approach, inspired by Dean Zimmerman (2011), questions the extent to which we should identify the present with a privileged reference frame. According to General Relativity (GR), not every spacetime is foliable: there will be spacetimes in which there are no universe-wide inertial frames. In fact:

> GR predicts that there will not, in worlds like ours, even be universe-wide inertial frames. It would be injudicious (to say the least!) [...] to suppose that being present is essentially tied to a physical phenomenon that does not actually exist! (196).

If this is the case, then it would seem infelicitous to use simultaneity—an inertial-frame-dependent relation—to tell us what is present. But that is exactly what the above argument does: it assumes that if x is present and y is simultaneous with x, then y is also present. Instead we should say that, at best, it is contingent whether inertial frames pick out the present. This options would require some modifications for how world states can play the role of reference frames if world states are also to report what is presently true across the universe, but here I am only interested in showing that the presentist has options available to her. In case this seems like cheating, I will return to the question of what ontological commitments are required by physics.[33]

---

[33] One might think that I've let the presentist off the hook by cheating: another, perfectly acceptable, way to talk about events occuring is to say that E occurs iff there is some world state that permanently implies E. On this definition, non-present events occur and therefore exist. So, contra the standard presentist view, there are non-present things that exist. But this need not be a case of cheating: it depends on what we make of events. If events are something like Chisolmian states of affairs—i.e. are proposition-like states of affairs—then the charge of cheating is hard to see. Here's Dean Zimmerman, a presentist, on the matter: "the existence of the more abstract states of affairs, after they have ceased to occur, strikes me as relatively unproblematic" (Zimmerman 2011, 174). Similarly, the presentist might claim that presentism is, at heart, a thesis about fundamental entities: there are no fundamental entities that are not present, though there may be derivative entities that are. (After writing this, I learned that Sam Baron has explored just

5.2.6 'At-t' Assertions

So far we have a temporal order that is constructed from tensed sentences. This is good, but it doesn't offer us a way to give a tenseless description of the world. Here I show how to get a tenseless description of the world. The easiest way to do this is to show how the relationalist can account for two sentence types that have "at-t" locutions: "p is true-at-t" and the kinds of temporally indexed statements required to solve the problem of change, such as "S-at-t is F".[34] I'll take each in turn.

The locution "true-at-t" is most naturally taken to indicate truth at a particular time. An easy way to make sense of truth at a time is to employ models: t is a time in model M, and we evaluate the truth of sentences by considering whether, in M, a sentence is true at t. Since we are dealing with time, the models we are after are temporal models. Using the results of the previous section, we can say that a temporal model is a world-state system.[35] To talk about truth in a model, we need to do a little work. First, we need a way to refer to specific times, i.e. world states. There are a number of ways one could denote world states, but one method that will work regardless of what we assume about the set of times (whether the set is continuous, for instance) is to define a bijection from world states to numbers. (An

---

this idea in (Baron 2014).) If, on the other hand, events are more "concrete", then the occurrence of non-present events does smack of cheating. But even then, one would have to argue that the presentist should accept this alternate definition of event occurrence over the ones given above.

[34] Adding "at-t" assertions to our vocabulary allows us to respond to an objection from eternal recurrence. In a world with eternal recurrence, the same time never occurs twice—but the same events do. If world states are nothing more than reports of events, they cannot be times, for then the same time would occur twice. One response to this objection is to deny the possibility of eternal recurrence. A second option is to say that there is a numerical distinction between events: in an idealized language there would be a different name for each event so that the same event never occurs more than once. (Thanks to Alexander Pruss for offering this objection and suggesting these two responses.) We now have a third option available as well: using the naming convention discussed in the next paragraph, we can say that world states themselves have different names—even if they report the same events—and are, therefore, numerically distinct.

[35] One could use partial world-state systems, but those won't, in general, accurately reflect what the world is like.

isomorphism is preferable for naming, but not required. In any case, I assume that there are at least as many numbers as there are world states in a given world-state system.) Using this method, a time is denoted by a number. A slightly more convenient naming system will subscript a number next to the letter t, so that "t_1" denotes some particular world state. I will adopt this convention and add another: "t" and "t'" will be used as variables for times.

Call the collection of times in a world-state system "T". Above I showed how to define *is earlier than* on world states; here I'll use the familiar symbol "$<$" for that relation. $\langle T, < \rangle$ is a temporal model. We can now define truth in a model:

- "ϕ" is true-at-t iff $t \in T$ and $A(t \rightarrow \phi)$.

The semantics for sentences with tense operators are then defined as follows:

- "$F\phi$" is true-at-t iff $\exists(t' > t)$["ϕ" is true-at-t']
- "$P\phi$" is true-at-t iff $\exists(t' < t)$["ϕ" is true-at-t']
- "$G\phi$" is true-at-t iff $\forall(t' > t)$["ϕ" is true-at-t']
- "$H\phi$" is true-at-t iff $\forall(t' < t)$["ϕ" is true-at-t']

Note that the only sentences for which these terms are defined are the sentences that are a part of the tense logic vocabulary.

Truth in a model allows us to expand our vocabulary to arrive at a tenseless description of the world. For instance, we can talk about temporal parts:

- "S-at-t is B" is true iff "S is B" is true-at-t.

This way of introducing truth-conditions for temporally indexed sentences results in an equivalence between the various formal solutions to the problem of change. I will say more about the equivalence in the following section when I address how my view answers the problem of change.

Before moving on to the metric, I want to note that my view denies reductionism about tense. In chapter two I said that reductionism about tense is the thesis that reality can be represented in tenseless terms, and that such a representation won't miss anything about reality by removing tensed statements from our description of reality. Since the tenseless description is an abstraction from the tensed description, the tensed description of reality is more accurate representation of what the world is fundamentally like than is the tenseless description. This means that a purely tenseless description does miss out on something, and therefore reductionism about tense is false.[36]

5.3 The Metric

As we have it, the temporal order can tell us that some event is earlier than another. A collection of ordered times allows us to define a metric on those times, which means that we can also speak of *how much* earlier one time is than another. In mathematics, a metric is a function, d, that maps pairs of points to a number; this function must obey four criteria:

(3) $d(x, y) \geq 0$ when $x \neq y$;

(4) $d(x, y) = 0$ iff $x = y$;

(5) $d(x, y) = d(y, x)$; and

(6) $d(x, y) + d(y, z) \geq d(x, z)$ (The Triangle Inequality).

Not all metrics are equal when it comes to measuring time. Consider a temporal model with three times, t_1, t_2, and t_3, where these three times are ordered linearly. One way to measure the distance between times is to say that the distance is 0 between any time and itself, and the distance between any two times is 1 otherwise.

---

[36] This does not say *what* is missing from the tenseless description, only *that* something is missing. At a general level, the tenseless description does not tell us which sentences are true simpliciter since tenseless descriptions are relative to a model. Notice that I did not say "which world states": I suspect that what we say about what sentences are true simpliciter will depend on whether we think that change is real because reality is changing or because of something else. For instance, if you are a presentist, you will say that change is real because reality is changing, in which case saying which sentences are true simpliciter amounts to saying which world state is true simpliciter. An eternalist, on the other hand, may want to talk about which world state*s* are true. But even then the eternalist will still maintain that there is an objective difference between the world states that are true and those that are not: that's part of what is required to deny reductionism about tense. (Thanks to Alexander Pruss for drawing my attention to the distinction between change being real and reality changing.)

So, t_1 is 0 units earlier than itself. Moreover, t_1 is 1 unit earlier than t_2 and also 1 unit earlier than t_3. But that doesn't seem right. Intuitively, t_3 is 2 units later than t_1. Or, to make this more concrete, the aforementioned metric implies that my first birthday is just as far away from my birth as my twenty-first birthday is—and that is clearly incorrect. This suggests that the above metric is not a good candidate for a *temporal* metric. In this section I will discuss what makes a metric a good candidate for the temporal metric, paying particular attention to work by Bradford Skow.

5.3.1 Intrinsic and Extrinsic Metrics

Bradford Skow says that temporal metrics are either intrinsic or extrinsic and that the difference between the two is that "extrinsic metrics do, and intrinsic metrics do not, involve 'reference to something external'—something other than times" (Skow 2010, 181). In other words, we can divide the collection of metric relations into two camps: those that refer to some feature of the world and those that don't; the latter are the intrinsic metrics, the former are the extrinsic metrics. Skow notes that there is an affinity between substantivalists and those who hold that the metric is intrinsic, as well as a proclivity for relationalists to hold that the metric is extrinsic: "Those who believe that the metric is intrinsic typically believe that time could pass in an otherwise empty universe; those who think that the metric is extrinsic typically believe that there can be no time without change" (184).

Skow talks as if the burden of identifying a temporal metric is a problem only for those who think that the temporal metric is extrinsic. Given the aforementioned affinity between relationalists and those who think the temporal metric is extrinsic, this is tantamount to saying that the problem of identifying a temporal metric is a problem that only relationalists face. But that is not the case.

This is easy to see by considering the above remarks on temporal models. A temporal model makes use of a temporal frame $\langle T, < \rangle$, where T is a set of times and $<$ is an ordering relation. A temporal metric will be a function that is defined over the members of T. One difference between the substantivalist and the relationalist is that the substantivalist gets the members of T for free: times are part and parcel of the substantivalist view. The relationalist, on the other hand, has to show how to get times from fundamental entities. This difference is orthogonal to the distinction between intrinsic and extrinsic metrics. An intrinsic temporal metric is a metric that is definable just given a temporal model. Regardless of where the times came from, once we have a set of times, any metric that is defined over those times is an intrinsic temporal metric as per Skow's characterization of intrinsic metrics. As we saw, this is a bad view to endorse, for not every definable metric is a good candidate for a temporal metric. This suggests that, no matter whether you are a substantivalist or a relationalist, you want to have an extrinsic temporal metric—at least insofar as you care about meeting some of the desiderata of the Folk Theory of Time.[37] So, the task of identifying a temporal metric is not one that only the relationalist faces.

5.3.2 "Something Else" and the Metric

Skow's proposal for identifying a metric as a temporal metric begins with a problem: How do we distinguish the claim that a temporal metric is extrinsic from the claim that there is no temporal metric at all? To see how this is a real worry for the proponent of an extrinsic temporal metric, consider Skow's example.

> Suppose that the temporal metric is extrinsic, and that it has the canonical analysis I have been using: for two temporal intervals to be the same length is for the Earth to rotate through the same number of degrees during each of them. An opponent denies that there is

[37] That said, a substantivalist will not want to dismiss intrinsic metrics entirely, since that is the only way to define a metric in an empty universe. Likewise, since an empty universe will have (at most) one time, the relationalist will be happy to concede that one cannot define a metric that implies that time passes.

> a temporal metric at all. But he still accepts that there is such a relation as *the earth rotates through the same number of degrees during interval x as during interval y.* Since he denies that there is a temporal metric, he denies that *this* relation is the temporal metric. It is not identical to the relation *temporal interval x is the same length as temporal interval y.* But what does this disagreement amount to? (Skow 2010, 186)

The problem, Skow notes, is that "many extrinsic relations on temporal intervals are formally eligible to be temporal metrics—they satisfy the relevant geometrical axioms—but nevertheless fail to be temporal metrics" (187–88).[38] So we need some other requirement to tell us which relations are eligible and which are not.

One solution to the problem is conventionalism.[39] The conventionalist says that some extrinsic relation—i.e. some relation that refers to something other than times, such as the Earth rotating around the sun—is the temporal metric because that relation fulfills certain semantic concerns that we have.[40] All candidates for the extrinsic metric are formally eligible, but one is selected over the other based on semantic concerns.

Skow thinks that conventionalism is not the best option. The conventionalist claims that "Necessarily, all the extrinsic relations that are candidate meanings for 'the same amount of time passes during x as during y' are equally qualified" (188). One who denies conventionalism must show that there is some non-formal feature that discriminates between candidates. In other words, all of the formally eligible candidates for an extrinsic temporal metric refer to something in the world. The question is whether there is some principled way to say that some features of the world offer better ways of measuring temporal distance than others. If there is a

[38] Gordon Belot (2011) makes a similar point for space. In chapter two, he uses only formal considerations (which for space involves whether there is a definable distance relation that obeys the three constraints of a metric) to offer several possible geometries of space.

[39] Prominent defenders of conventionalism in Grünbaum (1968), Mach (1960), and Poincaré (2001).

[40] See (Skow 2010, 188) and (Sider 2011, Ch. 4).

principled way to distinguish formally eligible candidates, then the conventionalist's claim is false.

Skow's argument against conventionalism leads him to proffer several alternative views:

- The temporal metric is the relation that plays the "temporal metric role" in the laws of nature (Skow 2010, 192–93).
- The temporal metric is the second-order relation *x and y instantiate the unique relation that plays the temporal metric role in the laws* (193).
- Of the candidates for the temporal metric, one is distinguished from the rest because it is more fundamental than the others (perhaps because the distinguished relation is fundamental) (194n).

The first and third options pare down the number of candidate relations by appealing either to the laws of nature or to fundamentality. The second option does not eliminate any formally eligible candidates but instead posits a second-order relation: *x and y instantiate* T, where T is "the unique relation that plays the temporal metric role in the laws" (194).

The second option is puzzling except in light of an objection one might raise to the first proposal.[41] As Skow puts it, on the first proposal, you can say either that the relation that plays the temporal metric role necessarily plays the role or not. The first horn of the dilemma seems to place "implausible restrictions on what the laws might be" (193).[42] The second horn faces a threat from skepticism: people in other worlds might be duped into believing that R is the temporal metric even though it's not (193). The second proposal avoids this threat by sidestepping the

[41] And perhaps the third proposal as well. Skow does not really consider the third proposal; he mentions it in a footnote and moves on. One could modify the following objection so that it applies to the third proposal by talking about whether what is fundamental is "fixed" across worlds.

[42] Though a nomic necessitarian might disagree.

issue of what first-order relation is the temporal metric since, on this proposal, no first-order relation is the temporal metric. Presumably it is necessary that "*x and y instantiate T*" is the temporal metric, but contingent which first-order relation is T. I'm not going to consider this proposal any further.

The first and third proposals each have problems that need to be addressed. The first proposal needs to address two questions. First, what does it mean for a relation to play the temporal metric role in the laws of nature? Second, how does the proposal address the skeptical worry, if the relation that plays the temporal metric role does not play that role necessarily? The third proposal needs to show how fundamentality can be used to pare down the number of formally eligible candidates for the temporal metric. Skow thinks that this is a formidable challenge: if the temporal metric is extrinsic, then the candidate relations "are extrinsic, they have analyses; and any relation with an analysis is non-fundamental" (194n). Moreover, Skow contends, a contrastive claim about fundamentality won't help since candidate relations look equally fundamental, which means that fundamentality does not allow us to pick out a unique candidate for the temporal metric. (The third proposal may also have to respond the worry about skepticism; see the first footnote in the previous paragraph.)

I think we can begin to address these problems by noting that the skeptical worry for the first approach is, in some ways, a mirror image of the problem the third approach faces. The skeptical worry for the first proposal arises because it is assumed that the laws of nature leave us with exactly one relation that can play the temporal metric role, and it might be too easy for the inhabitants of some world to be wrong about which relation is uniquely qualified to play that role. The worry for invoking fundamentality is that fundamentality eliminates too few options: there are several equally qualified and equally fundamental relations fit to be the temporal metric.

Given this, I'll now show how the problems each proposal faces can be addressed in the same manner. Each proposal will have a different way of telling us which features of the world are relevant when selecting a metric. On either proposal we will end up with several candidates; i.e. neither approach leaves us with a unique relation fit to be the temporal metric. Of the remaining candidates, we should then choose one based on semantic considerations, which is to say that the final step in selecting a temporal metric is a tempered form of conventionalism. Adding conventionalism in at the last step allows each proposal to address the problems it faces.

There several views on what the laws of nature are. Here I want to use the Best Systems view, championed by David Lewis (1973, 1983, 1994), since it allows for a clear statement of how laws of nature can tell us that some features of the world are better candidates than others for a temporal metric. We can think of the laws as a collection of sentences that talk about certain properties and relations that are instantiated in a world. Call them L-sentences. The Best Systems view of laws says that we include these in a true deductive system. The more L-sentences we include, the stronger, but more complex, our overall system. Likewise, the fewer L-sentences we include, the simpler, yet weaker, our overall system. Some L-sentences will be about temporal features of the world—they will talk about temporal properties and relations. The Best Systems view of laws says that the laws of nature are a part of a true deductive system that balances simplicity and strength. So, we can say that certain features of the world—e.g. certain kinds of processes, like the Earth rotating about the Sun—are better candidates for the temporal metric than others because those features allow for (or are included in) the true deductive system that achieves the ideal balance of strength and simplicity.

If we instead want to appeal to fundamentality, we can say that, for extrinsic relations R_1 and R_2, the more fundamental relation is the better candidate for the temporal metric. Candidate relations for an extrinsic temporal metric are comparative: such a relation refers to some process or processes (call these the "measurers"), and we judge the duration of some event or events by using the measurers as a measuring stick. We can then say that the more measurers a candidate relation refers to, the less fundamental that relation is. For instance, *the Earth rotates through the same number of degrees or a hummingbird's heart beats the same number of times during x as during y* is less fundamental than *the Earth rotates through the same number of degrees during x as during y* and *a hummingbird's heart beats the same number of times during x as during y.* One reason in favor of this view is that we can construct more complex relations from simpler ones, as is clear from the preceding example.[43] One question this approach faces is whether we should opt for the most fundamental relations that we can get. I do not know what to say about this, and I am not sure whether there is a determinate answer.[44]

Above I said that neither the laws of nature nor fundamentality will pick out a unique candidate as the temporal metric. To see this, consider two relations: *the Earth rotates through the same number of degrees during x as during y* and *Mars rotates through the same number of degrees during x as during y.* It seems that neither the laws of nature nor fundamentality give a reason to prefer one relation over the other. There is no obvious reason to think that a system that talks about Mars rather than Earth will not balance strength and simplicity as well as one that

[43] Note that the measurer in *the Earth rotates through the same number of degrees during x as during y* is the Earth rotating through d degrees. This suggest that this candidate for the temporal metric can be constructed from two relations: *the Earth rotates through d degrees during x* and $x = y$. Using these, we can say that *the Earth rotates through the same number of degrees during x as during y* is true iff the Earth rotates through d degrees during x, the Earth rotates through e degrees during y, and $d = e$.

[44] One reason is favor of always going for the more fundamental is this: *the Earth rotates through 2 degrees during x* and *the Earth rotates through 4 degrees during x* are each more fundamental than *the Earth rotates through some number of degrees during x* since the latter is an abstraction from either of the former. This leaves us with two relations that are as fundamental as one another and it is up to convention to choose the better candidate, which, as we'll see in the next paragraph, is easily dealt with.

talks about Earth instead of Mars, just as there is no reason to think that one reference frame better captures the temporal order than another. In the eyes of the theory, both are equal. Likewise, it is hard to see how fundamentality could say that a relation that talks about Earth is more fundamental than one that talks about Mars. So, on either approach, there is no reason to think that the laws of nature or fundamentality pick out a unique candidate to be the temporal metric.[45]

If neither the laws of nature nor fundamentality leave us with a single candidate for the temporal metric, we should choose one of the remaining candidates based on convenience. While both *the Earth rotates through the same number of degrees during x as during y* and *Mars rotates through the same number of degrees during x as during y* are candidate relations, the former is preferable. A complete rotation of the Earth about its axis takes approximately 24 hours whereas a complete rotation of Mars about its axis takes about 24 hours and 40 minutes.[46] Between the two candidate relations, *the Earth rotates through the same number of degrees during x as during y* is a more convenient relation not only because we live on Earth but also because the Martian day "doesn't coincide with the human body's natural rhythms" (Chmielewski 2015).[47] So, *the Earth rotates through the same number of degrees during x as during y* is the relation we should select as the temporal metric.

[45] There is a way in which the laws will leave us with just one candidate for the temporal metric. Take any metric function m and scale it by factor n; call the resulting metric m'. If m is a candidate for (a mathematical representation of) the temporal metric, there does not seem to be a reason why m' isn't a candidate too. Call such metrics "scale-factor-equivalent metrics". Just as "the drive took one hour" and "the drive took sixty minutes" say the same thing, so too do scale-factor-equivalent metrics. For this reason I will count scale-factor-equivalent metrics as equivalent; the choice between such metrics is what we can call the "choice of units" issue. A somewhat trivial way to guarantee only one candidate metric, then, is to let the scale factor be any real number.

[46] These two relations are scale-factor equivalent if we allow rational numbers as scalars. I'm ignoring this for the sake of illustration.

[47] There is a sense that Martian time should be measured differently from Earth time. The article points out that there is a discussion about what to call a Martian "day" and how to come up with a Martian calendar. One (detailed) proposal is (Šuráň 1997).

Conventionalism at the last stage of the selection process solves the problems both approaches to choosing an extrinsic temporal metric face. For the laws of nature approach, conventionalism wards off skeptical worries since the choice of a metric is up to those who will use the metric. Folks "just like us" can't end up with false beliefs about the temporal metric: as long as they choose from among the candidates not filtered out by the laws, they can't be mistaken about what the temporal metric is—they chose it, after all. For fundamentality, we can concede Skow's worry that there is no unique relation picked out by fundamentality but note that that is not a problem for the approach. As we've seen with the relation about a Martian day, we want some kind of conventionality in our choice of a metric.

5.4 Meeting the Requirements

I claimed that all of the requirements on a view of time can be met with a temporal order and a metric. I've just shown how to derive these two entities within an Aristotelian framework. Now it's time to show that this view does meet all of the desiderata on a view of time. In the previous chapter I used three different categories to group the following desiderata:

(1) Time must be connected to the causal order and with material objects.

(2) The view must address the problem of change.

(3) There must be a temporal order.

(4) The view must be rich enough for contemporary physics.

(5) The question of the passing or flow of time must be addressed.

(6) An account must be given of the modal profile of the past, present, and future.

In offering my view I have made it clear that the first and third requirements have been met. I've hinted at how the problem of change is solved, but will say more about the problem below. After addressing the problem of change, I will show how my view is rich enough for contemporary physics and what my view says about the passing or flow of time. I leave the discussion of time's modal profile to the next chapter, since time's modal profile offers reasons against endorsing some of the possible views of times mentioned above (though I will also show how my view satisfies this requirement).

5.4.1 Change

Solving the problem of change has an easy part and a hard part. The easy part is recognizing that temporal indices offer a formal way to solve the problem, and that there are four ways one might attempt to use temporal indices. If S is an object, t a time, and F a property, we have:

(1) S-at-t is F

(2) S is-at-t F

(3) S is F-at-t

(4) At t, S is F

The hard part of solving the problem of change is arguing that one of these solutions accurately describes the metaphysics of change.

Arguing for a particular solution to the problem of change is analogous to arguing for a particular metric to be the temporal metric. In the previous section we saw that there are several stages for arriving at a relation that plays the temporal metric role. The first stage is formal. The same is true for solving the problem of change. The formal solutions to the problem of change all meet the formal requirements for solving the problem; the solutions are, in a sense, equivalent.[48]

As Haslanger (1989b) noted, we don't want to endorse a conventionalist answer here. We want to choose one of the candidates because that candidate that most accurately reflects the way the world is. With temporal metrics, there were two

[48] For an argument to this effect, see (McCall and Lowe 2003, 2006).

ways to appeal to truths about the world in order to avoid convenionalism: the laws of nature and truths about fundamentality. For the problem of change, the relevant truths about the world are truths about objects and properties. Truths about objects and properties are the relevant truths because one would use those truths to justify their choice of a formal solution. For instance, one might say "'S-at-t if F' is the correct formal solution because eternalism about objects is true and objects have temporal parts."

The Aristotelian holds that substances are fundamental. As I noted in chapter one, this is compatible with eternalism about these objects, as well as the denial of eternalism about these objects. So, which of the above solutions is the one that you should endorse depends on more than just one's view of time. I've discussed how the relationalist can make sense of each solution to the problem of change. Arguing that one of these solutions is a better reflection of reality than the others goes beyond what I've set out to do.

5.4.2 Contemporary Physics

Contemporary physics is thought to provide the most difficult challenge for the relationalist. In the previous chapter I presented two kinds of challenges that have been posed to relationalism. The first problem is ontological: contemporary physical theories are field theories and any plausible version of relationalism seems not to be a field theory. The second problem is that relationalism cannot offer a rich enough model for our best scientific theories. Hartry Field argues that the relationalist has no good way to guarantee the truth of metrical claims. Michael Friedman argues that the relationalist cannot underwrite claims about the laws of nature. I'm going to argue that there is no ontological problem, and then show how the relationalist can provide a rich enough model to underwrite metrical claims and claim about the laws of nature.

There are two independent reasons to dismiss the ontological problem. The first reason is that the problem of fields can only be easily motivated for relationalism about space. Hartry Field and Tim Maudlin are suspicious of the relationalist's attempt to adopt fields because, to borrow Field's words, the relationalist must ascribe to fields geometric properties that "are exactly the same as the geometric properties that the substantivalist ascribes" to space (Field 1984, 41–42). In other words, since fields are spatially extended and have geometric properties, fields can be used as a cheap surrogate for substantival space—and that is what Field and Maudlin object to. The relationalist about time needs substances that change. Whether these substances are fields or particles is not a question the relationalist about time needs to answer. Particles and fields are material entities. It is uncontroversial that material entities are spatially extended.[49] But it is controversial whether these entities are also temporally extended—that's why there's an ongoing debate over eternalism about material objects. If fields are not temporally extended, then it is hard to see how it is objectionable for the relationalist to embrace a field ontology. For if fields are not temporally extended, then they cannot serve as a cheap surrogate for the geometric properties that the substantivalist ascribes to time. So, as long as fields are not temporally extended, the relationalist about time does not need to worry about adopting a field ontology.[50]

The second reason we can dismiss the ontological problem is that it seems to require an assumption that is both not argued for and controversial. The ontolog-

---

[49] At least, the kinds of material entities I'm concerned with are spatially extended. Perhaps there are particles that are material but not spatially extended, but I'm not going to complicate the picture by considering such things.

[50] Even if you hold that fields are temporally extended, you can avoid the ontological problem by making an additional claim: none of the temporally (and spatially) extended fields is spacetime, nor is any fusion of such fields. This avoids Maudlin's criticism—that the relationalist is really a substantivalist under a different name—since this kind of relationalist does not hold that one of the fields (or fusions of fields) is spacetime, much as one could be an anti-realist about the temporal metric while still affirming temporal relations.

ical problem for relationalism arises from the observation that models for our best physical theories include fields, along with the claim that we ought to admit into our ontology those entities that are in the domain of the models of our best physical theories. Taken together, these are supposed to force the relationalist to adopt a field ontology instead of a particle ontology, which then allows Field and Maudlin to voice the ontological problem for relationalism. Yet if we reflect on what it means to admit an entity into our ontology, the ontological problem loses its teeth.

If the ontological problem is a problem, the relationalist must be required to admit fields into her ontology. Within a permissive, Aristotelian ontology, we can be liberal about what exists even if we are not permissive about what is fundamental. Given this distinction, we can mean two things by "admit an entity into our ontology (on the basis of a scientific theory)": (i) the entity exists but is not fundamental or (ii) the entity is fundamental. The ontological problem is a problem only if we take (ii) as what it means to admit an entity into our ontology. For if the relationalist is only required to admit a non-fundamental entity, she can satisfy the demand by showing how fields can be derived from fundamental entities. I assume this can be done and leave it to the objector to show otherwise.[51] This means that (ii) is the only interpretation of what it means to admit an entity into one's ontology that can pose a problem for the relationalist. But there is no reason to think that realism about scientific models requires us to hold that the entities in scientific models are fundamental: there is no consensus on the nature of the ontological commitment that scientific realism requires; and it cannot in general be true that our best scientific models tell us what is fundamental since not all of the entities in models for chemistry, biology, geology, and so forth are fundamental.[52] And, even if

[51] To show that the assumption is not completely bogus, one could start by claiming that fields are nothing more than a collection of certain properties, such as charge, that particles have.

[52] Thanks to Meghan Page for discussion on this point.

there is a reason to privilege the models of physics as models that require ontological commitment about what is fundamental, Bain (2006) has shown how to reconstruct certain physical theories without appealing to a spacetime manifold. While this does not deny the existence of fields, it does raise a question of how we come to privilege certain models of our best physical theories over others. So, unless the objector has good reason to hold that (ii) is what scientific realism requires, the ontological problem is not a threatening problem for the relationalist.

With the ontological worry set aside, we can now focus on the objections from expressive power. In brief, these objections state that relationalist models are too weak (i) to underwrite all of the metrical claim that a physical theory needs and (ii) to induce theoretical properties and relations required by our best physical theories. Field (1984) and Friedman (1983) argue for (i) and (ii), respectively, from the claim that relationalism might leave the relationalist with too few points to quantify over. For Field, if there are too few points to quantify over, the relationalist will not be able to satisfy a plausible moderateness condition: all "magnitude relations between physical things and numbers must always be generated from relations among physical things" (Field 1984, 45). This is a problem, for the only way around it, Field claims, is to posit an infinite stock of primitive predicates to underwrite the magnitude relations. This is a bad result because there will be no stateable connection between such predicates, which means we will not be able to explain how different distances (such as *being two feet apart* and *being three feet apart*) are related.[53] For Friedman, the problem is not so much how many points there are but instead the work that those points are supposed to do. Friedman notes that a physical theory requires both an observational structure and a theoretical structure. For the relationalist, all of the properties and relations of the theoretical structure are supposed to be induced by the properties and relations of the observational structure. But, Friedman claims,

[53] Though see (Belot 2011, 25–27) for a reason not to take this as a bad result.

the points that make up the relationalist's observational structure cannot induce all the properties and relations that the theoretical structure requires (perhaps, but not necessarily, because there are too few points).

Both problems rely on a particular interpretation of relationalism. This interpretation of relationalism is what Gordon Belot (2011) calls *conservative relationalism*. The conservative relationalist tries to meet the objections from expressive power by considering only actual material configurations. Another kind of relationalism is what Belot calls *modal relationalism*. In contrast to conservative approaches, modal approaches consider "possible as well as actual configurations of matter" (38). Any version of relationalism is either conservative or modal. I will argue that modal relationalism can answer the objection from expressive power. So long as modal relationalism is a viable version of relationalism (which, as I'll argue, it is), the objection from expressive power is not fatal for relationalism.

The modal relationalist appeals to possible as well as actual geometric structures to answer the objection from expressive power. As long as any geometric structure that is not actually instantiated is possibly instantiated, the relationalist has a way to account for that structure. This means that the relationalist does not have to worry about there being "too few points" to underwrite certain metrical claims.

To show that modal relationalism is viable, we can look at the cost of adopting such a view. Belot notes that any version of modal relationalism must deny at least one of the following three theses:

Grounded: "If two worlds are geometric duplicates (i.e., agree about all intrinsic geometric facts) then they agree about all facts about geometric possibility."

Metric: "One specifies the intrinsic geometric facts that obtain at a relationalist world by specifying the distance relations between the material points at that world."

Ambition: "For every substantivalist world w with material configuration C, there is a relationalist world w^* whose material configuration C^* mirrors the geometry of C such that the facts about geometric possibility at w^* mirror those at w" (Belot 2011, 5).

Belot speaks about geometric possibility since he thinks that there are cases in which geometric possibility for space outstrips what is physically possible. For instance, if we want to say that it's geometrically possible that space is "infinite, even if we thought it physically impossible for matter to spread beyond a certain finite domain, or that space was infinite, even if the presence of infinitely many particles would cause it to roll up into a finite space" (50), we need a distinct variety of possibility to account for this claim about space. I will say more about this below. For now I only want to note that modal relationalism is viable as long as you don't think that relationalism needs to affirm all three theses.[54]

Here's a reason to think that relationalism about time does not need to affirm all three theses. Belot says that he is "happy to count any metric space as representing a possible way space could be" (27–28). He arrives at this conclusion because he thinks that ways of representing the distance structure of space serve as the primary guide to discerning what is a geometrically possible configuration of space. The relationalist about time can piggyback on this strategy, swapping language about space for language about time. Then, if Belot's arguments are convincing, the relationalist about time can draw the same conclusion: modal relationalism is viable even if it must deny one of Grounded, Metric, and Ambition.

In his attempt to offer a viable version of modal relationalism for each way of denying one of the above three theses, Belot adopts a view of nomic possibility to suit his needs. One can have a grounded, metric variety of modal relationalism

[54] So, even if Field's argument that modal approaches to relationalism must use a grounded variety of modality (Field 1984, SS9–10) is successful, there are still two varieties of modal relationalism that one can use.

that is unambitious by adapting Lewis' Best System view of the laws of nature for geometric possibility. A primitivist about laws is someone who asserts that "there could be two worlds that: (i) were each empty of matter; (ii) were duplicates of one another as far as their non-material contents go; yet (iii) differed in their laws and so differ, e.g., as to how massive point particles would move" (Belot 2011, 100). Adapting such a view for geometric possibility yields an ungrounded version of modal relationalism. Finally, a non-metric modal relationalism is the result of adapting nomic necessitarianism for geometric possibility. The nomic necessitarian holds the following three theses:

> N0: Physics is admirably adapted to discover the laws of nature at worlds like our own.
> N1: The laws of nature at a world are made true by facts about the non-geometric fundamental properties at that world.
> N2: The laws of nature at a world are given by a proposition corresponding to the set of worlds at which fundamental properties instantiated exactly match those of the given world. (107)

The relationalist about time can adopt any of these strategies, though it seems that our intuitions about what kinds of change are possible should be reflected in what are possible geometries of time. There are two ways this could turn out.

First, one might think that how things could change is restricted to what kinds of change are physically possible. In this case we can simply appeal to physical possibility to defend modal relationalism; we won't need to adapt a view of nomic possibility to come up with a distinct version of geometric possibility for time, as Belot did for geometric possibility about space. I'm inclined to think that we only need physical possibility, but I have no argument for that claim. Thankfully, nothing important depends on whether physical possibility is suited to yield geometric possibility for time.

Second, one could use one's intuitions about how things could change as a way to justify which of Grounded, Metric, and Ambition we should reject. Belot's arrives at the conclusion that any metric space represents a possible way space could be in part by holding that facts about fundamental ontology do not bear much weight in guiding our intuitions about what is spatially possible.[55] Even if ways of representing temporal distance play a role in discerning what is a geometrically possible structure of time, the relationalist about time must insist that our intuitions about how things could change play at least as significant a role in guiding our intuitions about the possible geometries of time. If one thinks that truths about how things could change are brute, that is a reason to follow the primitivist strategy above and deny Grounded. If one puts a lot of weight on the idea that change is bound to causation, and truths about causation will rule out certain metric spaces as possible representations of the ways things could change, then the relationalist has a good reason to give up on Ambition.[56] For even though Ambition does not say that every metric space represents the way a substantivalist world could be, the geometry of time in substantivalist worlds is not restricted by truths about causation insofar as time does not have causal powers. At the very least, the substantivalist will say that an empty world has a temporal geometry. The unambitious modal relationalist will not attempt to account for this world since there are no changing things in such a world and therefore no temporal geometry since there is no time. The relationalist will say that she does not need to account for such possibilities, since the geometry of time does not consider truths about causation. This move is a flat-footed response to some of the substantivalist's claims about what is a possible geometry of time: the relationalist just insists that certain geometries are not possible; that is, after

[55] From this, one can argue that the relationalist about space has good reason to endorse Ambition: if facts about fundamental ontology do not affect what is spatially possible, then it looks bad if the relationalist cannot match every substantival spatial possibility. Belot ultimately recommends a version of relationalism that accepts Ambition and Grounded, but denies Metric.

[56] Some argue for eternalism about material objects by appealing to similarities between space and time. If the argument in the text is correct, though, change provides a significant disanalogy between spatial and temporal possibility, which can be used to undermine arguments from analogy for eternalism about material objects.

all, just a part of the relationalist's theory.[57] So, including intuitions about change only helps the relationalist about time defend modal relationalism.

While we have an answer to Field's objection, it might seem that the relationalist has cheated when it comes to answering Friedman's objection. Friedman's objection is that the relationalist needs an observational structure (a mathematical representation of the temporal order) to induce theoretical properties and relations on a theoretical structure (a mathematical representation of the laws of nature), but the relationalist is unable to do this. By sneaking in truths about nomic (or geometric) possibility, the relationalist cheats his way out of the objection.

This objection can only be sustained against a relationalist that denies Grounded. Another way to phrase Friedman's objection is that the relationalist is unable to ground theoretical properties and relations in the properties and relations that the actual world instantiates. But both an unambitious and a non-metric modal relationalism have ways of grounding theoretical properties and relations. A best-systems approach uses actually instantiated properties and relations to yield the laws of nature and a nomic necessitarian approach says that the laws are grounded in the powers of the fundamental entities.

The two kinds of physics-based challenges to relationalism turn out not to be a problem for relationalism about time. The ontological worry for relationalism is not a problem for relationalism about time (though it does offer a challenge to the relationalist about space). The objections from expressive power can easily be handled by appealing to a modal relationalism: a relationalism that uses the laws of nature to underwrite claims about nomic possibility.

[57] This is not to say that the relationalist shouldn't be able to answer some of the substantivalist's critiques about possibility. Presented with a substantival possibility that he cannot account for, there will be cases in which the relationalist does need to show that things can't change like *that* in order to rule out the substantival possibility as a genuine possibility.

5.4.3 The Flow or Passing of Time

Part of the Folk Theory of time is that time passes or flows.[58] In the previous chapter I adamantly noted that this is a metaphor, and it is up to a view of time to give a reasonable interpretation of that metaphor. Here I follow Prior and say that time doesn't pass or flow; what the metaphor means is that things change. "Time itself" (to use an expression Prior would have demurred at) does not move: it only represents and measures. What passes or flows are changes. Expressions about the passage of time all get cashed out in terms of change and one's attitude towards that change. "Time flies when you're having fun," for instance, means something like "You don't notice how many changes happen when you're having fun."

5.5 Where are We?

Time consists of two entities, a temporal order and a metric. The temporal order is derived from changing substances. Tense logic provides a formal way of expressing how substances change. The resources of tense logic afford us enough expressive power to derive the temporal order, which tells us both what happens and the order in which changes occur. To derive the metric we need laws of nature to guarantee that there are processes the recur in the right way. The laws of nature give us a list of candidates that fufill the role of the temporal metric. Of those candidates, we select one based on convenience and linguistic practices, and that relation is the temporal metric. Since the temporal metric is defined in terms of processes that are permanently entailed by world-states, we gain the ability to say things such as "It has been two days since the war ended."

In this chapter I took a stance on several issues that are left open by my view. For instance, I hold that world-states are times; but there are other entities that can fill this role. (In the next chapter I will consider whether some of these other

[58] Note that the claim that time passes does not guarantee that the question of how fast it passes is sensible; the latter requires a metric.

candidates are better ones than world-states.) In terms of the theses presented in chapter two, what is essential for my view is (i) the denial that time is something independent; (ii) the acceptance of reductionism about the direction of time (see S5.2.3); and (iii) the denial of reductionism about tense (see the end of S5.2.6). Putting this all together, we have a $\overline{IT}D$ view.

CHAPTER SIX

Against The Competitors—Relationalism

In the previous chapter I presented my view of time. Along the way, I noted some of the advantages and consequences of the view. I'd like to think that the advantages alone are enough to convince you to endorse my view. But some may still wonder what my view has going for it that other views do not. That's what I'll focus on in this chapter and the next. There are two parts to this project. The first considers views that fall into the relationalist camp, the collection of views on which time is dependent on changing substances. The second considers my main rival: substantivalism, the view that time does not depend on changing substances but is instead a fundamental entity. Since my main concern is defending a relationalist view, the main aim of this chapter is to show that my view can better address some of the desiderata for a view of time than other relationalist views can. I do not intend to argue that the other views are implausible. In fact, if a functionalist attitude towards times is the correct attitude to have, we should expect that a relationalist view can be filled out several different ways.

Before proceeding, recall the taxonomy of views I introduced in chapter two. There I said that if time exists, one can ask whether time depends on other entities or not. I then said that there are two other theses a view of time needs to take a stance on: (i) reductionism about the direction of time and (ii) reductionism about tense. In this chapter and the next I group rival views according to whether time is something independent or something dependent. The reason for this is that I will argue that we should reject views on which time is something independent, so there is no reason to consider all the varieties of a substantivalist view. When considering alternate relationalist views, I will mention how (i) and (ii) bear on a particular view. In other words, I will consider how one's view of times affects what one can say about time.

6.1 Related Relationalisms

In the previous chapter I offered a list of possible views of times. Without argument, I endorsed the view that times are world states, which are a kind of abstracta. Here I want to consider other views of times. Specifically, I am going to point out problems for these views. I'll then raise a modal worry for views of times on which times are abstracta and discuss ways that the relationalist can respond to the modal worry.

6.2 Possible Views of Times

To derive the temporal order, the relationalist needs times. The relationalist about time maintains that time exists but is not a fundamental entity. Within the context of an Aristotelian metaphysical framework, this means that time is derived from fundamental entities. A key component of this kind of view consists of choosing an entity to fill the role of times. In chapter five I mentioned several possible views of times:

(1) Times are numbers.

(2) Times are abstracta.

(3) Times are Armstrong-style states of affairs.

(4) Times are sui generis concrete points or intervals of a timeline.

(5) Times are fusions of concrete points or regions along a spacelike hypersurface.[1]

"Abstracta" is an umbrella term for things like ersatz worlds and conjunctions of propositions; it does not mean that the other candidates are not abstractions from changing substances. The view of abstraction I presented in chapter three makes

[1] Thanks to Alexander Pruss for helpful discussion on possible views of times.

the above distinction superficial and allows for many possible views of times,[2] since the traditional way of thinking about abstract and concrete objects does not have a natural place in the Aristotelian framework; if there is a distinction along the traditional lines, it needs to be stipulated (e.g., abstract objects are those that lack causal powers). In fact, while one could maintain that some fundamental entity plays all of the roles of time (thus satisfying the functionalist view about times), I will argue that the relationalist ought to insist that times are derivative entities. In the previous chapter I promised reasons against adopting some of these entities as times. I'll consider the second through fourth views first, then come back to other kinds of abstracta.

6.3 Times as Locations

In the previous chapter I discussed two ways in which world states could be maximal. World states may be "implication maximal" in that, if "p" denotes a world state and "q" any sentence, "p" permanently implies "q" or "p" permanently implies "$\neg q$". World states might also be "content maximal": for instance, if "p" denotes a world state and "q" any other sentence, either "q" is a conjunct of "p" or "$\neg q$" is. For views on which times are the sort of thing that can be true or false, it is natural to think that times are at least implication maximal, and perhaps also content maximal. For short, I will say that, on such views, times "contain content". But for some of the views listed above, it is more natural not to think of times as being implication maximal or content maximal; instead it is more natural to see times are "pure" locations: we can pick out where we are in relation to other times and how times are ordered, but nothing beyond that (in part because, on these views, times are not the sort of thing that can be true or false, and both implication

[2] For instance, as Alexander Pruss brought to my attention, any maximal set of pairwise non-simultaneous instantaneous temporal parts of objects can function as a set of times, and therefore is a possible view of time. While this is a possible view of time, it is not plausible. In what follows I focus only on views that are plausible.

maximality and content maximality require that times be true or false). As I'll argue in S6.8, one can derive temporal locations from times if times contain content. Here I want to argue that the view that times are locations is not as well motivated as the view that times contain content. One upshot of this argument is that it places a restriction on how we interpret the views of times listed above.

If times are pure locations, we cannot appeal to times to tell us whether "Simba is king" is true at some future time t.[3] Perhaps you think that telling us whether Simba is king at t is not a primary role that time needs to fill, so it's not that big of a cost if we need to appeal to something other than times to tell us whether Simba is king. Even so, there should be a fact of the matter about whether Simba is king at t; if times can't give you the answer, then something else needs to. So, if times are locations then we need some other metaphysical commitments to take over some of the work that world states were put to in the previous chapter.

Here are five options one could try. First, one could appeal to the objects that exist at t. This requires eternalism about objects, though, which makes it an unattractive solution. As I argued in chapter two, one need not take a stance on eternalism in order to have a complete view of time. If the only plausible version of a view of times requires a stance on eternalism, so much the worse for that view of times. So, we should consider the other four options. A second option is to say that all sentences about the future are false.[4] This conflicts with intuitions that there are truths about the future. If this is the only way to defend the view that times are locations, so much the worse for the view—especially since there are other views of

[3] For comparison: given a view on which times contain content, we can appeal to times to tell us whether Simba is king at some future time in one of two ways. If times are content maximal, then we just need to look at, say, each conjunct of every future time to determine whether "Simba is king" is true at that time. If we have only (the weaker) implication maximality, we need to look to what is (permanently) implied by each future time (if times are world states; other views may use something other than permanent implication).

[4] In conversation, Patrick Todd and Amy Seymour have endorsed this kind of view. See also (Todd, (forthcoming)).

times that do not require the falsity of all sentences about the future. A third option is to employ some kind of derived entity that exists at each location and contains enough content to evaluate sentences like "Simba is king" at every location. Again, if this is what the view that times are locations requires, so much the worse for the view—in this case because one can get both content and locations by holding that times contain content. Availing ourselves of two different kinds of entities for two jobs when one entity can accomplish both jobs introduces an unnecessary redundancy into the theory. Likewise for a fourth option: one could hold that derived entities that exist now contain enough content to evaluate sentences at non-present times.[5] All that changes on this option is where the entity is located; there is still the problem of employing more entities than we need: What makes those entities unable to fill the role(s) that locations do? Fifth and finally, one could side with Merricks (2007) and deny that truths need truth-makers. This will make the location view work, but it does so at a significant cost: truths just don't have any explanation. Moreover, consider the sentence "It is always true that something is changing". The relationalist will accept this.[6] Given the semantics from chapter five, this sentence says that, at any time t, something is changing. If one sides with Merricks, then one will say that there is no truth-maker for "Something is changing" at any time—not even the present. This may not leave all truths ungrounded,[7] but it does show a significant burden the Merricksian must bear. What all this shows is that you can hold that times are locations without also endorsing something like worlds states only if you are prepared to subscribe to a controversial metaphysical thesis. Perhaps

[5] This is analogous to a strategy that Bigelow (1996) employ to defend presentism against the grounding objection: truths about the past must be grounded, but presentism cannot ground those truths.

[6] Cases of global freezes are tricky, so I ignore them here. But see (Shoemaker 1969) for an argument in favor of a freeze. Van Cleve (2011b) offers a response to Shoemaker's argument that avails itself of Prior's world states.

[7] See, for instance, (Melia 2005) on the distinction between truth-making and truth-makers.

one of these controversial theses is right, but my aim is to be as neutral as possible with respect to theses about eternalism and truth. So, in what follows I will consider whether there are any candidates that are significantly different from world states and offer a view of times on which times contain content.

6.4 Times as Numbers

Provided we have determined which set of numbers to use, numbers give us many features of the temporal order for free. Sets of numbers like $\mathbb{R}$ and $\mathbb{N}$ have well-defined ordering relations, which makes it easy to talk about temporal relations and the metric. This is not much of a surprise, given that we use mathematics to write down equations for physical theories. However, numbers cannot be times.

An intuitive way of using numbers as times is to treat numbers like (pure) temporal locations. As we saw above, though, the relationalist should not endorse this kind of view. So, if times are numbers we need to find a way to endow numbers with content about what is going on in the world. In other words, if times are numbers, then numbers need to be implication maximal or content maximal.

We need only consider the view that numbers are implication maximal. That numbers are content maximal seems like Pythagoreanism, which makes it a non-starter. So, if times are numbers, then numbers must be implication maximal.

If times are numbers, and numbers are implication maximal, numbers cannot be fundamental entities. To see this, suppose that numbers are fundamental entities and that numbers are implication maximal.[8] The temporal order, presumably, will be some set of numbers. The relationalist might be worried that, on this view, time does not depend on changing substances because numbers are all we need to get the temporal order. But as long as numbers (or sets) are derived entities,

[8] I'm not sure how one could motivate this view without something suspiciously similar to Pythagoreanism, but for the sake of argument I'll grant that there is reason to hold this view that does not amount to Pythagoreanism.

the relationalist cannot claim that time is not a derivative entity on this view. Furthermore, one might also say that the reason some particular set of numbers *is* time depends (in part) on substances changing: were there a world with no changing substances, the set of numbers that is time in this world would not be time in that world.[9] So this view seems consistent with a core relationalist claim that time depends for its existence on changing substances. Nonetheless, the relationalist often maintains the stronger thesis that time wholly depends for its existence on changing substances—and a part of what the relationalist means by this is that time has whatever content and structure it does because of the changing substances. On the view suggested by the objection, neither the content nor the order of time comes from changing substances; at best substances "participate in" the content and order given by numbers. (As I'll discuss below, one potential problem here is that it might be pure chance that substances do participate in the temporal order.) What this worry points out, then, is that relationalism is more than functionalism.[10] This problem is not unique to the view that times are numbers. Since I will refer to it again, let's call it the Fundamental Content Argument (FCA).

In chapter two I discussed Aristotle's view of numbers. He held that we derive (the natural) numbers by counting instances of some kind of thing. The kind of thing, a horse e.g., serves as our unit. One might use this strategy to derive numbers in a way that gives us enough content for the temporal order. Of course, if we use only horses to derive numbers, we will fall woefully short of the quantity of content required for the temporal order. Horses alone do not tell us whether bluebonnets are

---

[9] Thanks to Alexander Pruss for raising this point.

[10] While relationalism implies functionalism (see the discussion on substantivity in chapter three), the converse does not hold. A functionalist view of time, for instance, is consistent with substantivalism: if fields are fundamental entities, we might identify the gravitational field as space-time because it is the field best suited to play that role. (While functionalism and substantivalism are consistent, motivating such a combination of views is another matter, since neither view implies the other.)

blooming or whether the store is open. To think otherwise would be like holding that we could derive the entire content and structure of space from the spatial locations of every horse. The problem is not unique to using horses though: take any collection of entities less than the totality and there is going to be some content that gets left out. But if we use every entity to derive numbers, it begins to look as if we are deriving an entity that can play the role of numbers, rather than deriving numbers which then play the roles of times. So we can conclude that times are not numbers.[11] This is not an objection to the view that numbers can be derived from fundamental things. All I'm pointing out is that, if we use every fundamental entity to derive numbers, we've derived something that can play the role of numbers and the role of times, so it's a bit misleading to say that times are numbers.

6.5 Times as Concrete Points or Regions

For the sake of discussion I am going to label the fourth and fifth options:

SG: A time is a sui generis concrete point or interval of a timeline; and

FUS: A time is a fusion of concrete points or regions along a spacelike hypersurface.

As noted above, within an Aristotelian metaphysic the distinction between "concrete" and "abstract" is best drawn via stipulation. Here I will say that x is concrete just in case x has causal powers. This might lead to some counterintuitive judgments if taken as a full account of the difference between concrete and abstract objects, but for present purposes it is good enough. I'm going to argue that both of these views should be rejected because they require a stance on eternalism about objects. Specifically, I will argue that each requires eternalism about objects. But since a

[11] And one can run this argument even if one holds that numbers are divine ideas, as Augustine thought. For, in order for numbers to have enough content, God would need to derive numbers from all of the created substances. If God somehow endows the numbers with enough content, then we again are lead to the conclusion that something other than numbers is required to get enough content for the temporal order. One (extreme) way out of this is a Pythagorean view on which everything is reducible to numbers; though on this view one should take numbers as fundamental entities.

view of time should not force one to take a stand on eternalism about objects, these views should be rejected since there is at least one view of time that does not require a stance on eternalism about objects.

Both SG and FUS are manifold-first views. SG and FUS start with a timeline or spacetime manifold, respectively, and then derive times by dividing the timeline or spacetime. (My view, by contrast, constructs the temporal order from times.) A view that derives the temporal order from times is what I will call a "times-first" view. Times-first views are neutral with respect to eternalism, manifold-first views are not. A view of times that is neutral with respect to eternalism is better than a view that isn't. (Eternalism is not a thesis about time; so a view which forces one to take a stance on eternalism oversteps its bounds, and that is not a good thing.) So, a times-first view is better than a manifold-first view. Since we have at least one viable times-first view, we should reject both SG and FUS.

The (most) contentious claim in the previous paragraph is that manifold-first views are not neutral with respect to eternalism. Here's the reason such views are not neutral. SG defines times in terms of a timeline. Were we to write SG more exactly, we might write it as a conjunction: (i) there is a timeline T and (ii) t is a time just in case t is a sui generis concrete point or interval of T. By suitably modifying the FCA, we can conclude that it's a significant cost to hold that times are fundamental if SG is our view of times. So, one might think that (ii) is true because T is more fundamental than times. In other words, it is plausible that, according to SG the timeline is ontologically prior to the collection of times, and the substances are ontologically prior to the timeline (lest we become substantivalists): once we have the timeline we divide it into times. In the order of derivation, then, we start with substances, then derive the timeline, and then derive times.

FUS requires the existence of a four-dimensional manifold. A spacelike hypersurface is defined on a four-dimensional manifold. If we want to define times by appealing to spacelike hypersurfaces, then we need some kind of four-dimensional manifold.[12] So, to derive times, we first need to derive the four-dimensional manifold.[13] So, both the four-dimensional manifold and times are non-fundamental entities, but the manifold is more fundamental than the times.

Both SG and FUS seem to require eternalism. On each view we first derive the temporal order—the timeline for SG and the four-dimensional manifold for FUS—from substances, and then from the temporal order we derive times. The temporal order requires us to be able to talk about the past, present, and future. Since SG and FUS hold that the temporal order is ontologically prior to times, both views entail that the temporal order is concrete (i.e. has causal powers). (If x is derived from y and x has causal powers (i.e. is concrete), then y has causal powers: you can't give a derivative entity causal powers unless the entity from which it is derived has causal powers.) One could say the temporal order has causal powers because the temporal order is a substance—but that would contradict the relationalist's claim that the temporal order is not a substance. One could instead say that the temporal order has causal powers because, at every point or hypersurface of the temporal order, there is some substance that has causal powers—though that would require eternalism about objects, which would make the view inferior to other views of times. The only remaining explanation is to say that a future time's causal powers can be grounded in a present substance—though that seems like a difficult claim

[12] Moreover, it's not clear that the existence of a hypersurface is independent of its geometry. Since General Relativity says that geometric properties depend on the arrangement of matter in the manifold, in order to have a geometry and therefore exist, it looks like matter must exist at future hypersurfaces. (Thanks to Alexander Pruss for bring this to my attention.)

[13] This four-dimensional manifold cannot be fundamental; if it were fundamental, then either substantivalism is true, or we have to posit a relation between the manifold and substances in order to get enough content for times (for similar reasons as noted above and as will be discussed below). The only way to say that the manifold is fundamental is if one holds both monism and eternalism—but then it begins to look like one is really endorsing a version of substantivalism.

to defend.[14] Since none of these options are appealing, we should abandon SG and FUS as views of times.[15]

6.6 Times as Armstrong-style States of Affairs

The easiest way to introduce Armstrong-style states of affairs is by contrast. Plantinga (1974) says that states of affairs are Platonic entities that exist whether or not they obtain. On Plantinga's view, Obama not winning a second term is just as real a state of affairs as Obama winning a second term, even though the former did not obtain. On Armstrong's (1997) view, by contrast, a state of affairs exists iff it obtains. So, according to Armstrong, Obama not winning a second term is not a state of affairs since it did not obtain (and therefore does not exist). As Alexander Pruss notes, "It is tempting to call these states of affairs 'concrete' but some of these states of affairs are also abstract, like the state of affairs of seven being odd" (Pruss 2011, 215). For this reason we can think of Armstrong-style states of affairs as facts.[16] Given this, I will treat the view that times are facts as a merely verbal variant of the view that times are Armstrong-style states of affairs.

If we employ states of affairs as times, not just any state of affairs is a time. As I write this, there is a car driving by my window. If times are the content-bearers of the temporal order, then we must be able to infer truths about what I am doing, what the weather is like, and so on from any time. But I can not infer such truths

---

[14] Perhaps one could motivate such a claim given Baron's Priority Presentism, though Baron does not make such a claim: he only argues that present fundamental entities can ground future and past non-fundamental entities. Why the non-fundamental entities should also have causal powers would need to be argued for.

[15] One could drop the claim that times are concrete. If one does this, though, it seems as if the manifold-first view is a merely verbal variant of the times-first view. In both cases we derive some kind of abstracta, and the only difference is whether we divide an abstractum into several abstracta (and thus have a manifold-first view), or use some abstracta to compose some further abstractum (and thus have a times-first view).

[16] Though we might not want to identify states of affairs with facts—at least if you are a friend of truthmaker theories. See (Textor 2014).

just from a car driving by my window. So, if Armstrong-style states of affairs are used as times, we need to be careful in choosing which states of affairs we call times. In fact, we will need states of affairs that are maximal.

If states of affairs are maximal, they are neither implication maximal nor content maximal.[17] Instead, we might say that a state of affairs is maximal if it is a complete "snapshot" of the world. This might tempt us toward something like the definition of a moment given by Belnap and Green (1994): a moment is a spatially complete but instantaneous event. We might say that a time is a spatially complete but instantaneous state of affairs.[18] The problem with this approach is that it provides us with a temporal order only if eternalism about objects is true. For suppose that presentism (which is one view that denies eternalism) is true. According to the presentist, only those objects that presently exist exist at all. If presentism is true, then there is only ever one state of affairs—the present—since nothing exists except for the present. We can then say that a time is a spatially complete state of affairs, but there is only ever one time because there is only ever one state of affairs. But in order to account for all the content that the temporal order requires, we need more than one time.[19] In fact, we will need all states of affairs to exist; but this just is to say that we need eternalism about objects to be true: plausibly, a state of affairs obtains (and therefore exists) only if the objects the state of affairs is about exist. And if we need eternalism to be true, we should reject the view that times are states of affairs.

---

[17] Unless, of course, states of affairs are sentences. But then the resulting view is a merely verbal variant of mine.

[18] This will need further conjuncts to account for states of affairs like seven being odd, but since the claim in the text is the core of the view and it doesn't work, I won't bother with the details.

[19] One way to accomplish this is to appeal to some kind of abstracta; but then we are better off saying that the abstracta are times, not the states of affairs, because the abstracta are the ones that contain the content of the past, present, and future—and that is what matters for the temporal order. (Van Cleve (2011a) puts this point well when discussing the passage of time.)

Perhaps you think you can avoid the above argument by offering a way for past and future states of affairs to be "contained" in the present state of affairs. If successful, then one can hold that times are states of affairs regardless of the truth of eternalism about objects. But this won't work. A state of affairs exists iff it obtains. Substances change, and either there are states of affairs about those changes or not. In the world of Doctor Who, The Doctor is able to regenerate when mortally wounded. Regeneration allows The Doctor to escape death, though after the regenerative process he inhabits a different body. The Doctor maintains self-identity (including past memories) throughout the whole process, but The Doctor has numerically distinct bodies at either end of the process. For ease of exposition, I'll use the names of the actors who play The Doctor. At the start of one regeneration cycle we have the state of affairs of David Tennant being The Doctor, and at the end of the cycle we have the state of affairs of Matt Smith being The Doctor. If both states of affairs exist, they obtain. But (barring certain time travel cases) David Tennant being The Doctor and Matt Smith being The Doctor cannot co-obtain.[20] You can't have a future state of affairs contained in a present state of affairs, for that seems to require David Tennant being The Doctor and Matt Smith being The Doctor co-obtaining. Thus, the only way this view of times is viable is if eternalism is true.

One objection to the above argument is that you can have David Tennant *having been* The Doctor coinciding with with the state of affairs of Matt Smith *being* the Doctor.[21] (Note that this denies that a state of affairs obtains only if the objects the state of affairs is about also exist.) If that's the case, then future states of affairs can be contained in present ones. I am sympathetic to this response—

[20] So, this seems to rule out presentism (or at least non-eternalism), which is a mark against the view since it is not neutral with respect to eternalism.

[21] Thanks to Alexander Pruss for raising this objection.

because it makes this view look suspiciously close to the one offered in the previous chapter. If a state of affairs exists iff it obtains, then David Tennant *having been* The Doctor is a state of affairs but David Tennant *being* The Doctor is not. Even though the former is a state of affairs and the latter is not, it would be odd if there were no connection between David Tennant having been The Doctor and David Tennant being The Doctor. And the natural connection between them is that David Tennant having been The Doctor is a state of affairs because David Tennant being The Doctor *was* a state of affairs. But "David Tennant being The Doctor was a state of affairs" just seems a verbal variant of "It was the case that David Tennant is The Doctor", which is exactly what my view would say. So, if we grant the objection, it looks as if the view that times are Armstrong-style states of affairs is a verbal variant of the view that times are world states. Therefore, either the view requires eternalism (in which case it should be rejected), or seems to be a merely verbal variant on what I offered in the previous chapter.

6.7 Times as Abstracta

In chapter five we saw one view of times on which times are abstracta. I'll now consider some other versions of this kind of view, then present a problem that most of these views face, the problem of modal flexibility. As I noted above, "abstracta" does not denote just any abstraction; as I use the term, it refers to abstractions that lack causal powers. (In terms of mapping some of the views we've considered: SG and FUS entail that times have causal powers, Armstrong-style states of affairs may have causal powers—chopping a log looks like it involves causal powers but the number seven being odd does not—and abstracta do not have causal powers.) There are many entities that are abstracta and could be called times. I'm only going to consider a small number of these views; the problem for most of these views rests on an assumption that many of these views make: that a time is identical to some abstractum.

In addition to lacking causal powers, if some kind of abstracta is to play the role of times, those abstracta must also provide content for the temporal order and must be able to be ordered. One obvious candidate for this role is the event. Put in a pre-theoretic way, events are things that happen: yesterday's bike ride, the coffee in my mug cooling, the upcoming presidential election, and so on.[22] It seems beyond question that events offer a way to supply content; coupled with temporal relations to put events in the right order, it looks like we have a candidate for the temporal order.

Almost, but not quite. Following Ulrich Meyer, let's call someone an event-relationalist if he wants to use events to give content to the temporal order. Meyer says that the event-relationalist faces a dilemma, and neither horn is acceptable. The event-relationalist has a choice about the ontological priority of events: either events are fundamental entities or they are not. On the first horn, if events comprise the temporal order we are left with "nothing plausible to say about how ordinary material objects relate to time" (Meyer 2013, 19). This is another instance of a problem we've already seen: the whole point of the relationalist project is to say that time is intimately related to material objects, so much so that time depends for its existence on material objects. Meyer notes that if events are fundamental entities and are "the primary occupants of the time series [i.e. temporal order] then material objects relate to time only indirectly, by *participating* in events that stand in temporal relations to one another" (17). He goes on to argue that there is no good

[22] The relationship between events and states of affairs is not settled. Chisholm (1976), for instance, holds that events are a kind of state of affairs (though Chisholm does not hold Armstrong's view of states of affairs). All of this gets complicated fairly quickly, so I proceed by treating events and states of affairs as distinct things. Note that one way of seeing that states of affairs and events are distinct is that, understood in the pre-theoretic way, events involve things that can change. Since seven's being prime is not something that can change, this suggests that it is not an event, even though seven being prime is a state of affairs.

way of saying what it is for a material object to participate in an event. Without a good account of what it is for an object to participate in an event, the tie between time and substances is weakened.

Meyer's challenge to the event-relationalist need not be a show-stopper. A more significant worry for taking events as fundamental entities is the FCA: even if we have a good account of how substances participate in events, the resulting view of time looks less like a relationalist view and more like a substantivalist view. For if events are fundamental, the temporal order is independent of substances. This is a problem for the relationalist. Either there is only one temporal order comprised of these fundamental events or there are multiple temporal orders. If there is only one, then given that the temporal order is independent of substances, it looks like pure luck that the changing substances do in fact participate in the events in the temporal order. If, on the other hand, there are multiple temporal orders, each of which is comprised of events that are fundamental entities, it is hard to see how those temporal orders depend on changing substances.[23] And if the temporal orders do not depend on changing substances, then the connection between time and the world is made even weaker. Thus this horn of the dilemma appears to be off the table for the relationalist.

On the second horn—the view that events are not fundamental—the event-relationalist needs to presuppose the very thing he is attempting to construct: the temporal order. If events are not fundamental, they need to be derived from something. Since events are about things that happen to material objects or at least involve material objects, it is sensible to hold that material objects (or substances) are ontologically prior to events. Indeed, this is the view introduced by Strawson

[23] One could claim that the temporal orders are grounded in the changing substances in the same way that the possible is grounded in the actual. Then the multiple temporal orders do depend on changing substances insofar as the temporal orders are grounded in those substances. But then it looks like events are not fundamental after all.

(1959). But we cannot get away with just material objects: I am not an event; my getting off the couch is an event. So, events must also refer to the properties that material objects have. But even this is not enough: the ticking of my watch is an event. Since my watch ticks on a regular basis, we can say either that the ticking of my watch is a recurring event, or that it is one of many such events, each of which is numerically distinct from the others (thus the ticking of my watch is an event type, of which there are many tokens). Neither option is tenable. We'll consider the latter first. Suppose my watch is a really good watch, so much so that each ticking is qualitatively indistinguishable from the others.[24] Then the only way to distinguish the tickings from one another is by the time of their occurrence. But this is a problem: events must be constructed from more fundamental entities and this construction

> must be completed, and their identity conditions settled, before we can talk about events entering into temporal or other relations to one another. Metaphysically complex events could inherit their temporal relations from the temporal features of their constituents, but that is not a view event-relationalists can endorse without undermining their central contention that events are the basic temporal entities. That role would instead be played by the temporally ordered constituents of events. If events are incapable of recurring then they cannot be constructed out of something else *and* be the primary occupants of the [temporal order]. (Meyer 2013, 16)

In brief: we already need (part of) the temporal order in order to construct the temporal order from events—and that's a problem.

The event-relationalist could instead say that events recur. If he claims this, events are not suited to play the role of times. Consider the ticking of my watch. If the ticking of my watch is a recurring event, it cannot include any content about what goes on apart from my watch's ticking. (The event may also have to preclude content about the atoms that make up my watch, as well as any content about the

[24] If you are a Leibnizian, this may rule out the proposal from the start, for it violates the principle that if x and y are indiscernible, x is identical to y.

state of motion of my watch.) In order for the ticking of my watch to be a recurring event, it needs to be rather limited in what it says.[25] We are left with a trade-off: the more content a recurring event contains, the fewer times it recurs. This creates a problem for using recurring events as times. The temporal order is supposed to tell us about *everything* that happens in time. When I want to know who won the last Tour de France, the ticking of my watch cannot tell me the answer, no matter how many times it ticks. So, recurring events cannot play the role of times—on their own, recurring events do not provide enough content. If we try to appeal to recurring events with more content, we risk running into the problem posed for non-recurring events.

The way around this problem is to consider collections or fusions of recurring events. Here it is hard to see how those collections will both give us enough content and be comprised solely of recurring events, though. If there are events that occur only once in the history of the world (the Incarnation, for instance), a temporal order constructed from only recurring events will not say anything about one-time events. And to add non-recurring events into the picture is to abandon the view that times are events.

The above discussion of events has some general morals for views on which times are abstracta. The first moral is no surprise: times are not fundamental entities. If times are fundamental, there will be a disconnect between the temporal order and the world; such a disconnect goes against the spirit of relationalism. The second moral is that we should look to the world for our source of times. Non-recurring events require some kind of timeline and recurring events tell us too little to give the complete temporal order. This suggests that our view of times should be more closely tied to the fundamental. Moreover, the preceding discussion has shown

[25] And this is the easy case. Suppose Tom's eating a burrito is a recurring event. In order for this event to recur, it cannot tell us much at all about Tom—his physiological state, where he is, etc.—or the burrito he is eating—how large it is, what it contains, etc.

that times need to be maximal, and that events should be derivable from our view of times (in the ontological hierarchy, times are in between fundamental entities and events).

Since the problem with using recurring events as times is that recurring events are not maximal with respect to content, it is worth saying a bit more about what it means for a time to be maximal with respect to content. This is distinct from the question of whether times are implication maximal or content maximal. The issue at hand is one of scope: can a time be maximal even if it does not imply or does not have as a conjunct a certain kind of proposition? The details will differ with each view, though the spirit will remain the same. For present purposes, then, I will look at two views that use propositions to construct times.

Thomas Crisp and Craig Bourne both hold that times are maximal propositions. They disagree on what it takes to be a maximal proposition. Crisp, for instance, defines time as

Crispy times: x is a time $=_{df}$ For some class C of propositions such that C is *maximal* and *consistent*, $x = [\forall y(y \in C \supset y \text{ is true})]$,

where "(i) a class C is maximal iff, for every proposition p, either p or its denial is a member of C, (ii) a class C is consistent iff, possibly, every member of C is true, and (iii) '$[\forall y(y \in C \supset y \text{ is true})]$' . . . denotes a tenseless proposition" (Crisp 2007, 99–100). (i) entails that past- and future-tensed propositions are members of C; so each time provides a complete history of the world (100).[26] Bourne, on the other hand, defines times thus:

Bournian Times: t is a time $=_{df}$ $t = \langle \mu, n \rangle$, where $n \in \mathbb{R}$ (Bourne 2006, 54).

[26] Crisp adds that there is an ersatz B-series: "a series of abstract times ordered by a primitive *earlier-than* relation" (Crisp 2007, 102). While one could hold that there are many ersatz B-series that hold between all possible times, Crisp advises the presentist to claim that there is only one ersatz B-series and it is the one whose members are "only some of the abstract times—those that did, do or will represent the world" (104).

μ is a maximally consistent set of u-propositions: present tensed propositions that contain neither a P nor an F operator (Bourne 2006, 53).[27] The second member of the pair is the date. Bourne says nothing more about dates than that they are numbers. To complete the picture we need an earlier-than relation. Bourne calls the earlier-than relation the E-relation. The E-relation holds among times and is an ersatz earlier-than relation since it holds among abstract objects, not concrete ones. So times are ordered pairs of the form $t = \langle \mu, n \rangle$ that are members of the set of sets of ordered pairs of the form $t = \langle \mu, n \rangle$ that are E-related (54).

There are a number of differences between their views, but the salient one is that, for Crisp, all information about the past and future is included in every time, whereas for Bourne, a time contains only information about what is present according to that time. Bourne says that maximality is only with respect to u-propositions; Crisp says that maximality is with respect to any proposition whatsoever. I don't think it matters much whether we choose Crisp's or Bourne's definition, though Bourne's view of maximality provides a lower bound on what it takes for a time to be maximal. While the details will depend on the view, we can begin to see how to state the maximality condition. If we are using entities of kind k to construct times, then a time t is maximal iff, for every entity e of kind k, t either includes e or includes its opposite. What it means for a time to include an entity and what it means for an entity to have an opposite need to be filled in by the view. (For instance, on the view that times are world states that are only implication maximal, "includes e" means permanently implies "e" and "includes its opposite" means permanently implies "$\neg e$".)

As I've formulated it, maximality requires quantifying over certain derivative entities. This should not be a problem given the semantics for grounding discussed

[27] u-propositions are distinguished from e-propositions: propositions that contain a P or F operator.

in chapter three. But if this seems like a problem (as it might when we are talking about propositions), then you can adjust the view in a manner similar to that in chapter five: introduce axioms to talk about times rather than quantified claims. That's all I'll say about maximality.

Crisp's and Bourne's views say that times are bearers of truth and falsity. But not all views of times appeal to propositions or sentences. Some views, such as Markosian's (2004), talk about times representing the world. Within an Aristotelian framework, we have a nice way to explain representation. We can say that if x represents y, x is derived from y. Times represent the world insofar as times are abstractions from the world. Depending on what we can make of merely possible representations, this might restrict times to only those entities that did, do, or will represent the world.

6.8 Modal Flexibility

Yesterday I could have gone running. As a matter of fact, I went cycling. Yesterday also could have been the last (or the first) moment of time; but, as it turns out, it wasn't. Views of times—especially those on which times are abstracta—tend to have trouble accounting for the truth of these kinds of counterfactual claims about the past. These views get into trouble because the most plausible way of offering semantics that combine tense and modality makes false some counterfactual claims about the past that seem true. We can call such views *modally inflexible.*

The chief cause of modal inflexibility is an identification of a time with a certain abstracta. Padgett and Byerly (2014) offer a view of times that avoids this cause: they say that times are not identical to, but rather constituted by, abstracta. But the view offered in that paper is the exception that proves the rule. I am going to rehearse their argument, but do so in a way that generalizes it so it is more easily adapted for other views of times. I'll then discuss ways out of the argument and close our look at modal flexibility by showing how my view can accept all of the assumptions of Padgett and Byerly's argument but avoid the untoward consequence.

Padgett and Byerly employ four assumptions in their argument, the second of which is a schema for an assumption:

IDEN: If x is identical to y, then necessarily x is identical to y.

AT-T: For any proposition p and time t, p is true-at-t iff X, where X is a claim about how the view in question relates propositions to times.

SA: "Yesterday" is a rigid designator (at least in some cases), and "Dan could have gone cycling yesterday" is true iff [possibly, Dan is cycling] is true-at-t, where t is yesterday.

MA: For any proposition p and time t: $\Diamond p$ is true-at-t iff there's some world w in which t is a time and p is true-at-t in w.

These four assumptions allow them to defend the following premise:

(6) If view of times V entails that times are identical to some abstracta, then "Dan could have gone running yesterday" is false.

They take "Dan could have gone cycling yesterday" to be true (even though, as a matter of fact, Dan did not go cycling yesterday). Since view of times V entails a falsehood, so much the worse for view V. Note that whether 6 can be defended depends on whether, for any view of times on which times are identical to an abstracta, there is an instance of AT-T. This is not a real worry for their argument, though: the right-hand side of the biconditional is a statement entailed by a view of times, since the right-hand side of the biconditional is a statement about how propositions are related to times. For instance, Bourne relates propositions to times through set membership. On Bourne's view, p is true-at-t iff $p \in \mu$ when $t = \langle \mu, d \rangle$. Padgett and Byerly's response to the argument is to come up with a view of times on which the antecedent of 6 is not satisfied. But escaping this argument does not guarantee that their view is immune from modal inflexibility, so they then show how their alternative is modally flexible.

To see how they defend 6 for some specific view, consider Crisp's view of times. On Crisp's view of times, propositions are related to times by conjunction. As Padgett and Byerly put it, "on Crisp's view, to refer to a time just is to refer to a conjunction of propositions" (Padgett and Byerly 2014, 493). Thus the relevant instance of AT-T is: p is true-at-t iff p is a conjunct of t. This means that, when we talk about yesterday, "yesterday" refers to all and only those propositions that were true yesterday. But now we can show that Crisp's view is modally inflexible. Here is their argument, quoted at length:

> Let T be the referent of "yesterday" and c be the proposition [Dan is cycling]. Since T is a maximal, consistent conjunction, either $\Diamond c$ is a conjunct of T or not. But on neither option can Crisp coherently account for the truth of "Dan could have gone cycling yesterday."
> Suppose first that $\Diamond c$ is not a conjunct of T. Since T is maximal, $\neg\Diamond c$ is a conjunct of T. If that's the case, then [it's not possible that Dan is cycling] was true yesterday. Crisp is likely to hold that, for any proposition p and time t, p is true-at-t iff p is a conjunct of t. And if [it's not possible that Dan went cycling yesterday] was true yesterday, then [it's possible that Dan went cycling] was not true yesterday. And if that's the case, then "Dan could have gone cycling yesterday" is not true. So, contrary to our assumption, Crisp's view entails that Dan could not have cycled yesterday. Thus, on the first horn of our dilemma, Crisp cannot coherently account for the truth of "Dan could have gone cycling yesterday."
> The Crispian should not be happy with the first horn of the dilemma. She should instead claim that $\Diamond c$ is a conjunct of T. This seems like a promising move—but it too will not allow Crisp to coherently account for the truth of "Dan could have gone cycling yesterday." For, again, Crisp will claim that for all proposition p and times t, p is true-at-t iff p is a conjunct of t. But then it follows that if $\Diamond c$ is a conjunct of T, then $\Diamond c$ is true-at-T. However, MA is an attractive view. Thus, if Crisp wants to claim that $\Diamond c$ is true-at-T, he must claim that there is some world w in which c is true-at-T. But Crisp cannot coherently claim that there is such a world. For, on Crisp's account, T is identical to the conjunction of propositions true yesterday. Moreover, "yesterday" rigidly refers to T. "Dan could have gone cycling yesterday" is true only if there is some world

> in which "yesterday" refers to a time at which "Dan is cycling" is true. But there is no such world. Hence it is not the case that Dan could have gone cycling. (Padgett and Byerly 2014, 493–94)

At a more general level, the argument is this. "Dan went cycling yesterday" (c) and "Dan went running yesterday" (r) cannot both be true. As a matter of fact, c is true, but r could have been true, i.e. $\Diamond r$ is true. Since times are maximal, either c or $\neg c$ is true-at-t, where t is yesterday. Clearly, $\neg c$ is not true-at-t, since c is true-at-t. But if t is yesterday in this world, then t is yesterday in all worlds (by IDEN). Once we have AT-T filled in appropriately, SA and MA entail that "Dan could have gone running yesterday" is true only if c is true-at-t and r is true-at-t, since r must be true-at-t in order for $\Diamond r$ to be true. So long as there is an instance of AT-T for a view of times on which the relationship between some abstracta and times is non-contingent, that view of times can be shown to be modally inflexible.[28]

Padgett and Byerly's appeal to constitution metaphysics is not the only way to avoid the argument. Another way to answer the argument begins by poking at MA a little bit. MA is a way to combine tense and modality. As they say,

> One intuitive way to deal with such a combination is the $T \times W$ approach, the details of which can be found in (Thomason 1984). The basic idea behind this approach is that it adds a temporal dimension to possible worlds semantics. Adding this dimension allows us to talk not just about what is true in a world; with the added temporal dimension we can talk about what is true at a certain time in a particular world. As we've seen, having our possible worlds semantics enriched in this way is advantageous since we make claims about what could have happened at some time. The easiest way to add a temporal dimension to possible worlds semantics is to start with a non-empty set T of times and a set W of worlds. The set T is linearly ordered by the earlier-than relation. A linear history, h, is a subset of T such that for all $t_1, t_2 \in h$, $t_1 < t_2$ or $t_2 < t_1$ or

---

[28] Padgett and Byerly's solution is to modify Bourne's approach: a time is not identical to a set of u-propositions but is instead constituted by that set. Furthermore, they hold that "if T is a time with date d, then T essentially has d as its date" (Padgett and Byerly 2014, 499). Put together, they say that t is a time provided that $\exists\mu\exists d[\langle\mu, d\rangle$ constitutes t, and $\forall w\forall\mu^*\forall d^*(w$ is a world $\rightarrow (\langle\mu^*, d^*\rangle$ constitutes t in $w \leftrightarrow (d = d^*$ and $\langle\mu^*, d^*\rangle$ obtains in $w)))]$, where "obtain" means that the members of μ are all true on date d.

> $t_1 = t_2$. Modality is brought into play by $\approx$, a three-place relation on $T \times W \times W$ such that (1) for all t, $\approx_t$ is an equivalence relation, and (2) for $w_1, w_2 \in W$ and $t^* \in T$, if $w_1 \approx_t w_2$ and $t^* < t$, then $w_1 \approx_{t^*} w_2$ (Thomason 1984, 146). If the set of equivalence relations $\approx_t$ is non-empty, then there are worlds that have the same past and hence share times. (Padgett and Byerly 2014, 498)

So, if $w_1 \approx_t w_2$, then w_1 and w_2 have the same history until t. If worlds share times, we can introduce semantics for modal propositions: for any proposition p and time t, $\Diamond p$ is true-at-t iff there is some world w in which t is a time and p is true-at-t in w. And this just is MA.[29]

The non-technical motivation behind the formal apparatus is that we want a way to temporally slice possible worlds. In other words, we take the worlds as they are and then partition them in a way that allows us to compare what goes on in different worlds at some time. This treats time more as location markers than as content bearers. On the $T \times W$ approach a time t has content because the partition of the world that corresponds to t has content. Thus far in this dissertation times have been treated primarily as content bearers and secondarily as location markers. When we begin to combine time and modality, though, we need to be careful about which role of times is primary. Unless you are a Lewisian about possible worlds, possible worlds must be derived entities.[30] If times are primarily content bearers, then worlds are constructed by, and gain their content from, collections of times. In

---

[29] It is also worth including their footnote to this argument:

> It is worth noting that even if time branches, one still needs something like the $T \times W$ approach to capture the full gambit of counterfactual claims. Consider, for instance, the claim "yesterday could have been the first day the world existed." Even if time branches, there is no past time in our world relative to which this claim might be true in the future. If it's true that yesterday could have been the first day the world existed, it can only be because there is some other temporal structure—something like a possible world—in which yesterday actually was the first day the world existed. So, one still needs something like the $T \times W$ approach. (Padgett and Byerly 2014, 498n)

[30] This is not to say that Lewisians about possible worlds must maintain that worlds are fundamental entities. Rather, it seems that the only way for one to hold that possible worlds are fundamental entities is to be a Lewisian about worlds.

other words, worlds are derived from times. If times are primarily location markers, worlds already have their content, and times are simply a way of slicing up that content. But, as I argued above, this requires a commitment to eternalism—at least when deriving a possible world that represents the actual world. So, we should say that worlds are derived from times.

We can now see more clearly why views on which times are abstracta run into problems. The views that we have considered treat times primarily as content bearers. Thus we are to construct worlds out of collections of times. When we do this, the content of a time gets "carried over" to other worlds, and that is what gives rise to modal inflexibility. A time contains the same content in every world. If t is a time, then if t is a part of the temporal order of two distinct worlds, those two worlds must agree about what happens at t. Thus, if "yesterday" rigidly designates t, then the only worlds accessible from this one are worlds in which t is a part of the temporal order. And that is what gives rise to modal inflexibility. To avoid this problem, we should instead insist that "yesterday" rigidly refers to a temporal *location*. In other words, when we make temporal claims within the scope of a modal operator, the temporal terms are referring primarily to location markers, and secondarily to content bearers; that is, we first find the temporal location, and then we evaluate the content. The trick is figuring out how to do this within the metaphysical system that we have.

The proposed strategy suggests that we need location markers and content bearers (i.e. times). One could employ two unrelated kinds of entities. But within an Aristotelian framework one need not do that. Instead, one can derive the location markers from the content bearers. The strategy here takes advantage of the relationship between the temporal order and the metric that we saw in chapter five. I'll first offer the overall picture and then fill in the requisite details.

The main strategy is to modify MA. I am going to show how to do this for world states and leave it as an exercise for the reader to fill in the details for other views of times. Recall that if p is a world state, then p is a present truth that permanently entails everything that is now true. If "$W\phi$" means that ϕ is a world state, there are two ways to define world states:

WS: $W\phi$ iff $\phi \wedge \forall\psi(\psi \rightarrow A(\phi \rightarrow \psi))$

WS*: $W\phi$ iff $S\phi \wedge \forall\psi[S(\phi \wedge \psi) \rightarrow A(\phi \rightarrow \psi)]$.

"$S\alpha$" ("It is sometimes the case that α") is defined as "$P\alpha \vee \alpha \vee F\alpha$" and "$A\alpha$" ("It is always the case that α") is defined as "$H\alpha \wedge \alpha \wedge G\alpha$". (Recall that world states are (at least) implication maximal: if "p" denotes a world state and "q" any sentence, either "p" permanently implies "q" or it permanently implies "$\neg q$". I make no assumptions about the linearity of the future.) We then name world states according to some convention so we say that a sentence is true at a world state. For simplicity I'll name world states eponymously here. The obvious instance of AT-T is that for any sentence ψ and world state ϕ, "ψ" is true-at-"ϕ" iff $A(\phi \rightarrow \psi)$. If we take the rest of the assumptions as stated, we can now run the argument for modal inflexibility.

But we shouldn't take MA as stated. Given the above remarks about temporal location, we should modify MA to:

MA*: For any sentence q and world state p: "$\Diamond q$" is true-at-"p" iff there's some ℓ and world state s such that (i) $L(\ell, p)$ and (ii) $\Diamond L(\ell, s)$ and (iii) "q" is true-at-"s".

"$L(\ell, p)$" means that ℓ is the (temporal) location of p. Supposing p is the current world state, MA* tells us that q is possibly true just in case there is some world state s that could have had the same temporal location as the (actual) present one, and that, according to s, q is true. Of the three conjuncts on the right-hand side of the biconditional in MA*, the first two need to be explained. I'll take each in turn.

In chapter five I urged that, while the temporal order has a metric in our world, we should think of the two as distinct. Here we find a nice payoff of that advice. Recall that the metric is set by choosing some relation, such as *the earth rotates through the same number of degrees during x as during y*, which gives us temporal units. The process of selecting the metric begins by considering those relations that satisfy certain geometric axioms. Among those relations we consider only those that describe or are derived from physically possible (or fundamental) processes. From that collection of candidates we choose one as the metric.

In chapter five the candidates for the metric made reference to actual objects, e.g. the rotation of the earth around the sun. This approach is fine for the most part, but what if there are worlds that share the same laws of nature, but have none of the objects that our world has? Can we say that those worlds have the same candidates for the metric as does our world? Thankfully I do not need to answer that last question.[31] I do not need to answer the question because of the kinds of counterfactual claims that the argument for modal inflexibility is concerned with. The argument for modal inflexibility has a bite because the counterfactual claims it considers are supposed to be obviously true; and these counterfactual claims are obviously true because, for instance, it does not seem a far off possibility that I could have gone running yesterday (even though I actually went cycling). In other words, the worlds that we are concerned with in evaluating these counterfactual claims are ones that are close to ours in terms of what there is and what has happened. So, the nearby worlds that we use to evaluate such counterfactual claims will have the same processes as in our world, and thus the same metric relations. Possibility claims about the world ending might require worlds that are a little further removed

[31] Though I'm inclined to say that the answer is affirmative. It seems like the laws specify types of processes—e.g. body m_1 rotating about body m_2—and the types of processes that are candidates should remain the same across worlds; whether there are tokens of the process is a different matter. And as far as using tokens of a process to set the metric, see what follows in the main text.

from actuality, but even then the question is whether our world—with it's particular collection of substances and changes they have undergone—could have ended yesterday.

If we have worlds with the same metric relations, we can use the processes from which those relations are derived as location markers. Let's take *the earth rotates through the same number of degrees during x as during y* as our metric relation. Since this is a metric relation, we can model it with a metric function d. In mathematics, a metric is a function that maps pairs of points to a number (and meets several axioms, given in chapter five). To get out of the problem of modal inflexibility, we want content-less (temporal) locations at which things happen; so we don't want the world states in a world-state system to comprise the domain of d since they contain content. We can get a set of points that is devoid of content by choosing a set of numbers that is isomorphic to a world-state system; specifically, we want a set of numbers whose cardinality is equal to that of the actual world-state system and on which we can define the same ordering relations that we find in the actual world-state system.

I assume that for any world-state system there is a set of numbers isomorphic to that world-state system.[32] The set of numbers that represents the set of world states is not unique, and this is advantageous. Just as we pick a metric relation based on convenience, here we pick one of the sets that is isomorphic to the set of world states based on convenience.

Filling in the details for how we so choose a set of numbers is not difficult. We start with the observation that *the earth rotates through the same number of degrees during x as during y* gives us equivalence classes of processes, where the members of a given equivalence class are of the same temporal duration as each other. So, there is an equivalence class of processes during which the earth rotates through 0

[32] It is likely that one of $\mathbb{Z}$, $\mathbb{N}$, $\mathbb{Q}$, $\mathbb{Q} \cap [0, \infty)$, $\mathbb{R}$, or $[0, \infty)$ will be isomorphic.

degrees, through 1 degree, and so on.[33] Consider the equivalence class of processes during which the earth rotates through 360 degrees.[34] This is the equivalence class of processes that take one day. Since this is a convenient unit of temporal duration, we can ensure that our metric function says that the temporal distance between the beginning and end of these processes is 1. To do this, we pick one of the processes from the equivalence class and map the world state at which the process starts to 0 and the world state at which the process ends to 1. (Since world states permanently entail whatever occurs at them, if B is a sentence describing the beginning of the chosen process, then there is some world state p such that p permanently entails B.) This gives us the foundations for a mathematical function to describe our chosen temporal metric relation. We also have a way to map world states to numbers that respects our choice of a temporal metric. Call this map "f". We can now say that, for some world state p, $L(\ell, p)$ iff $f(p) = \ell$.

Let A be the (or an) actual world-state system and S be an appropriate set of numbers.[35] In the previous paragraph I showed how we can define a map $f : A \rightarrow S$ so that we can model our chosen temporal metric relation. We can now give truth conditions for the second conjunct of MA*: $\Diamond L(\ell, s)$. Let A' be a possible world-state system that is distinct from A but meets the aforementioned restrictions on possibility. We can say that if $f : A \rightarrow S$ is well-defined then so is $f : A' \rightarrow S$.

[33] So, if the metric function m took sentences as arguments, then for each degree d that the Earth rotates, the set $\{P \mid p_b$ reports the beginning of P, p_e reports the end of P, and $m(p_b, p_e) = d\}$ is an equivalence class.

[34] To say that the earth rotates *through* 0 degrees is to say that it does not rotate at all. So, the equivalence class of processes during which the earth rotates through 0 degrees is distinct from the one during which the earth rotates through 360 degrees.

[35] A world-state system is an actual world-state system if (roughly) it correctly reports what goes on when in our world. There are likely going to be many world-state systems, not all of which correctly report what goes on when in our world. For instance, if one can construct a world-state system on which some world state permanently implies a sentence about a unicorn galloping on the ground, that world-state system is not an actual world-state system; at best it is a possible world-system. Whether it is a possible world-state system depends, in part, on whether unicorns are possible.

Given this, we can say that $\Diamond L(\ell, s)$ iff (i) $f(p) = \ell$, (ii) there is some A' such that s is a member of A' and $f(s) = \ell$, and (iii) A and A' are sufficiently matched. (The third conjunct is purposefully underspecified: when evaluating counterfactual claims about what could have happened it is clear that we want to consider only those worlds that share the actual world's history but how much of the past other world's have to share is contextually determined.[36]) What I have done here is offer a way to "stack" possible temporal orders on top of one another and see what is going on at the same location in each of them. If we are using numbers to keep track of where we are in the temporal order, p and s have the same location just in case they are assigned the same number. Moreover, how A and A' are matched should determine how f maps world states to numbers: similar or identical world states should be mapped to the same number. For instance, if a, b, and c are consecutive world states in A and a, b, and d are consecutive world states in A', then we should require that $f(a) = x$ when $f : A \to S$ iff $f(a) = x$ when $f : A' \to S$, and similarly for the other world states.

One might try to simplify this whole account by removing the need for numbers.[37] One way to fill out this idea is to hold that there is an isomorphism $h : A \to A'$ that we can use. Then we can say that "$\Diamond q$" is true-at-"p" iff there is some $h : A \to A'$ such that (i) $h(p) = s$ and (ii) "q" is true-at-"s", and (iii) A and A' are sufficiently matched. Whether this is a distinct view depends on how we defend the claim that there is an isomorphism from A to A'. For clarity, let $f : A \to S$ and $g : A' \to S$. If g has an inverse, then $h(x) = g^{-1}(f(x))$. So, the simplification is the result of working out the consequences of the above. If one can justify the existence of an isomorphism

[36] For some considerations on what we should require when looking for worlds that sufficiently match ours, see (Lewis 1979).

[37] Thanks to Alexander Pruss for suggesting this idea.

from A to A' in some other way, however, then we have another alternative to MA (and perhaps a better alternative than MA*).

Note that locations are not playing the role of times. Indeed, as per the argument in S6.3, locations are not, on their own, suited to play the role of times. (Note that even on the times-as-numbers view discussed above, numbers need content and therefore are not suitable to play the role of locations as discussed here. This looks as if it will create an additional complication for one who claims that times are numbers: if times are numbers, and numbers contain content, then numbers cannot be used as locations, as they were here.) What I've shown here is that locations do have a place in one's view of time—but that place is not playing the role of times.

Before concluding this chapter, I want to make a brief remark about where the numbers come from. Given an Aristotelian view of numbers, one might think it is infelicitous to map to distinct set of world states to the same set of numbers, since numbers are derived from what exists in a world. One easy way around this worry is to say that numbers are fundamental. But there are other options. One alternative is to be a structuralist. If you are a structuralist about numbers, it is easy to derive numbers in the way that we need. The structuralist is not concerned with the question of what numbers are, but instead with the question of what things can fill various roles in an overall structure. Given this, f is guaranteed to be an isomorphism if world states play the role of numbers. This might make you think that it is cheating to use "the same" set of numbers when talking about locations in other worlds. But we can appeal to considerations for what makes two sets of world states sufficiently matched. Which world state we map to 0 depends on those considerations. We can then say that the two corresponding world states are mapped to "the same" location because they are able to fit correctly into the overall structure—and that seems like a fairly nice result. We are able to say that what it means for both $f(p)$ and $f(q)$ to be assigned 0 is that p and q fulfill the same structural role in the overall temporal order. If any explanation for grounding possibility claims about what could have happened at a time is plausible, it seems that this surely is.

If other views on which times are abstracta can mimic this response, then those views are safe from the argument for modal inflexibility. Note, though, that it requires a commitment to the hierarchical ontology that I favor, as well as the view of abstraction that I put forth in chapter three. What I've proposed also gives a nice semantics for combining time and modality, though it is restricted to nomologically accessible worlds. But any relationalist account seems confined to that restriction. Transworld temporal comparisons can happen only within a certain set of worlds; that is a cost of the view, but it seems like a pretty reasonable one. I cannot see any important reason for needing to be able to talk about what happened yesterday in a world that is nomologically inaccessible from ours.

6.9 Conclusion

In this chapter I've argued that the most plausible view of times for the relationalist is one on which times are abstracta. Abstracta are derived entities that lack causal powers. There are a number of candidates that the relationalist could choose as times. Each of these candidates must have a way of answering the argument for modal inflexibility, though. I offered one way around the argument that offers a way of combining semantics for time and modality. I showed how this works if we use world states as times.

CHAPTER SEVEN

Against The Competitors—Substantivalism

In chapters four and five we considered contrastive reasons for favoring substantivalism over relationalism. In chapter four we saw how substantivalists argue that both the ontology and the ideology of substantivalism are better suited for handling contemporary physics than is relationalism. In chapter five I argued that this is not the case; i.e. the contrastive reasons for favoring substantivalism over relationalism do not hold up. In this chapter I argue for two claims. First, that relationalism is better than substantivalism. Second, that substantivalism is false. Before getting to that, I need to do some stage setting. First, we need to see what substantivalism looks like within an Aristotelian metaphysic. Second, we need to consider whether the substantivalist should hold that it is time and/or space that is fundamental, or whether the substantivalist should say that it is spacetime that is fundamental. Third, we need to consider what, exactly, a realist attitude towards our best physical theories commits us to. Once we have all this on the table, I will argue that substantivalism is false.

7.1 Aristotelian Substantivalism

Recall that the metaphysical framework within which I am operating has a hierarchical ontology on which non-fundamental entities are derived from fundamental ones. In the terminology of chapter two, the fundamental entities are independent, while the non-fundamental entities are dependent. The dependence here is ontological: if x is an independent entity, then whether x exists does not depend on the existence of other entities. The substantivalist thesis is that time (or spacetime) is a fundamental, and therefore an independent, entity. This says nothing about what this fundamental entity is like—about whether the direction of time is reducible to something else, or whether tense is reducible to something else; the basic substantivalist thesis only asserts that time (or spacetime) is a fundamental entity.

If spacetime is a fundamental entity, then the substantivalist should maintain that regions and points of spacetime are derivative. If it were the other way around—i.e. if regions or points were the fundamental entities—it would be hard to see the difference between relationalism and substantivalism. If regions or points were fundamental, then spacetime would have to be derived. If that were the case, the resulting view would seem to be a merely verbal variant of relationalism, especially if the relations between points or regions were also derived. For these reasons I take substantivalism to be the view that time (or spacetime) is a fundamental entity, and its regions or points are derivative. (One could also claim that spacetime as well as regions or points are fundamental, but this seems unmotivated for reasons we'll discuss below.) Whether it's time or spacetime that is a fundamental entity is a substantive question, so we'll need to consider how the substantivalist should answer that question.

7.2 Space And/Or Time, or Spacetime?

In chapter two I discussed how physical theories changed from talking about space and time to talking about spacetime with the advent of relativity. At a minimum, this is a conceptual change. In chapter three I argued that, for the relationalist, it is only a conceptual change: the relationalist has the resources to derive the required entities for spacetime and for time. For the substantivalist, this conceptual change raises a substantive metaphysical question: is it time that is fundamental (and perhaps space as well), or is it spacetime that is fundamental? As we saw in the previous paragraph, the substantivalist must claim that at least one of these entities is fundamental. Parsimony recommends that at most one of these entities is fundamental.

I'm going to argue that the substantivalist should hold that spacetime is fundamental. Note that this is not to say that the substantivalist has to reject space and time. The substantivalist that we are considering is still an Aristotelian. This means that she has the tools for deriving entities. So long as she can derive time from spacetime, the substantivalist can claim that time exists (but is not fundamental). This means that the relationalist and substantivalist agree that time exists and is a derivative entity; they disagree about whether spacetime is a fundamental entity. Since this disagreement is about what is fundamental, it is a substantive disagreement.

The substantivalist has four options for what is fundamental:

- Spacetime
- Space only
- Time only
- Space and Time

Given that this project is concerned with time, the second option is off the table: a substantivalist about space alone ends up being a relationalist (or perhaps an anti-realist) about time. To choose among the remaining three options, we should appeal to parsimony.

Here, parsimony is judged by considering fundamental entities.[1] A theory can have ontological parsimony with respect to types of fundamental entities or with respect to tokens of those types. Schaffer (2014b) points out that it is more art than science when comparing theories on the basis of entity types. (Though if two theories have all of the same types of entities, then the obvious point of comparison is with the number of tokens.)

[1] Jonathan Schaffer (2014b) discusses the difference between ontological parsimony à la Occam's Razor and fundamental ontological parsimony à la his Laser. The dictum regarding Schaffer's Laser is to refrain from multiplying *fundamental* entities beyond necessity.

Parsimony isn't everything. The simplest theory, ontologically speaking, posits no entities.[2] But such a theory might not get us much. If theory X has fewer fundamental entities than Y, but we get far more explanatory power out of Y, then X's parsimony is counterbalanced by Y's fecundity, or strength. A theory is supposed to provide explanations. If a theory sacrifices explanatory power for the sake of fewer entities, that is a mark against the theory. The ideal is to strike a balance between the number of fundamental entities and the fecundity (or explanatory power) of the theory.[3]

The challenges posed to relationalism in chapter four can be seen as challenges to relationalism's fecundity. In chapter five I argued that relationalism is at least as fecund as substantivalism by showing how the relationalist can meet all of the desiderata on a view of time. So, in what follows I assume that relationalism and substantivalism are equals with respect to explanatory power. This means that whether relationalism is a better theory than substantivalism comes down to whether relationalism is more parsimonious than substantivalism with respect to fundamental entities. I'm now going to argue that there is only one version of substantivalism—Spacetime Wholism—that rivals relationalism with respect to parsimony.[4] I then argue that spacetime wholism is false.

---

[2] Cf., Swinburne, who argues that the simplest theory posits one entity with infinite power. See (Swinburne 2004, Ch. 7) and (Swinburne 2010, Ch. 3).

[3] Schaffer calls this "Bang for the Buck" methodology, and it is not unlike the ideal of strength and simplicity sought after in the Best Systems approach to the laws of nature. Within an Aristotelian framework, we can say that the goal is to "optimally balance minimization of fundamental entities with maximization of derivative entities (especially useful ones)" (Schaffer 2014b, 652).

[4] This does not, on its own, imply that each of these versions of substantivalism are false. To reach that conclusion we need something like the following: other things being equal, if theory X beats theory Y on parsimony, then Y is false. (Part of the "other things being equal" clause will have to say that both theories are good candidates for whatever it is that the theory is supposed to explain, lest we have spurious theories ruling out legitimate ones.) I do assume that other things are equal and that contrastive parsimony claims are a guide to the truth. So, I take it that showing that relationalism beats a certain version of substantivalism on parsimony is sufficient to conclude that that version of substantivalism is false.

7.2.1 Space and Time

Substantivalism about time requires that time is a different kind of entity than substances. Substances have causal powers, time does not. (*Spacetime* can reasonably be seen as having causal powers; but we'll get to that in a bit.) If time is a different kind of thing than substances, then an ontology on which time is fundamental has one more kind of thing than an ontology on which time is not fundamental. So, the substantivalist about time is committed to an additional kind of entity that the relationalist is not. Give that relationalism and substantivalism are equally fecund, parsimony rules in favor of relationalism.

One might object: perhaps the relationalist about time is a substantivalist about space, and the substantivalist about time is a relationalist about space. Space, like time, just seems to be a different kind of thing than substances. So, the relationalist here is also committed to an additional kind of entity in his fundamental ontology. So parsimony does not rule in favor of relationalism.

The objection is a problem for my argument only if (i) pairing relationalism about time with substantivalism about space is superior to double relationalism (i.e. relationalism about both time and space) and (ii) it's not the case that double substantivalism (substantivalism about both time and space) is superior to substantivalism about time paired with relationalism about space. In other words, a problem arises only if the relationalist about time should also endorse an additional fundamental entity—space—while the substantivalist about time need not do that. If we found ourselves in that situation, the ontological cost of relationalism about time would be equal to that of substantivalism about time. The conjunction of (i) and (ii) seems prima facie implausible (in part because it is a strong claim); I'll corroborate this intuition by offering reasons to think that each of (i) and (ii) are false—though all I need is that one of (i) and (ii) is false.

Relationalism about time seems logically independent from relationalism about space: there are no entailments from, say, relationalism about time to substantivalism about space. Even so, Leibniz's arguments for relationalism about space apply to relationalism about time as well. This gives us evidence that, even if one could consistently hold relationalism about time and substantivalism about space, we should take double relationalism or double substantivalism. If Leibniz is right, relationalism wins doubly on parsimony, since the substantivalist about time should also be a substantivalist about space. If Leibniz is wrong, we can reject the evidential connection between relationalism about space and relationalism about time. If there is no evidential connection between relationalism about space and about time, relationalists and substantivalists about time should accept or reject relationalism about space together. If that's the case, then relationalism still comes out ahead for ontological cost since both sides would gain an entity were they to accept space as a fundamental entity. So, whatever we make of Leibniz's arguments, the relationalist is still ahead in ontological cost by at least one kind of entity.

One could press the point that there is some additional, non-Leibnizian reason for relationalists about time to accept space as a fundamental entity, but there is no such reason for the substantivalist about time to do so. As it stands, this is only a skeleton of an argument. To fill it out in a convincing way places a double burden of proof on the objector. First, the objector needs to specify what the additional reason is. Second, the objector needs to provide reasons for thinking that whether we endorse substantivalism about space comes down to this (as of now mysterious) additional reason. Neither point has an obvious answer, so I don't see the need to address this any further. Thus, if substantivalism wants to rival relationalism on parsimony, the substantivalist should not say that time is fundamental. Since the substantivalist must hold that one of time or spacetime is fundamental, this means that the substantivalist should say that spacetime is fundamental.

7.2.2 Spacetime

Not every view of spacetime affords the substantivalist a rival for relationalism, however. If spacetime is just another kind of entity at the fundamental level, substantivalism at best ties relationalism on parsimony—but does so only if the relationalist about time is also a substantivalist about space; double relationalism will still beat substantivalism on parsimony. Unless the substantivalist has a convincing argument for the relationalist about time to be a substantivalist about space, a better bet is to say that spacetime is one of the substances. Then substantivalism gains the upper hand: for if the relationalist about time is a substantivalist about space, then the relationalist has one more kind of entity than the substantivalist about spacetime; and the double relationalist only ties substantivalism about spacetime with respect to parsimony.[5] Though as far as substances go, spacetime would be an odd one, so much so that it might seem a stretch to count it as a substance. For instance:

- Spacetime must be four-dimensional since time is. If you're not a four-dimensionalist about other substances, this is a considerable difference between spacetime and other substances—so much so that it would not be unreasonable to claim that spacetime is a different kind of entity than other substances. The only way around this is to hold that all substances are four-dimensional. Given what I said in the previous chapter, a forced commitment to eternalism about objects is a mark against a view of time, and so, one would think, with a view of spacetime (though that might be quite a bit more controversial).

---

[5] How much the additional token weighs against substantivalism will depend, of course, on how many other entities there already are. If you think that particles are substances, then adding 1 substance to the approximately 10^{80} particles in our universe is not much of a cost. On the other hand, if you think there are only three substances, then adding an additional entity seems a bit more costly.

- On a Newtonian view of spacetime, spacetime is a powerless substance (which might mean it's not a substance at all). Yet even if spacetime has causal powers, it might very well lack certain (important) powers that other substances have: some candidates include powers related to generation, locomotion, free will, and reasoning.
- A substance can be located at or contained in spacetime, but not conversely.[6] (One might be able to say that a *region* of spacetime is contained in a substance, but spacetime as a whole cannot be contained in a substance that is distinct from spacetime.) Moreover, one can reasonably assert that spacetime necessarily overlaps every (material) substance. But that is not true of any other substance: there is no (other) substance that necessarily overlaps every other substance.[7]

I do not have a worked-out view of substances, so I cannot say that these considerations decisively tell us that spacetime is not a substance. If these considerations rule out spacetime as a substance, then relationalism still looks more attractive in terms of ontological cost. But even if these considerations are not sufficient to rule out spacetime as a substance, the aforementioned idiosyncrasies of spacetime may well be enough to argue that the substantivalist is committed to an additional type of entity without appealing to the category of substance. In other words, even if spacetime is a substance it is a different kind of substance than all the others, so much so that parsimony should consider kinds of substances instead of just substances.

[6] Why only "can be"? Angels and God would be substances that are not contained in spacetime. (Thanks to Alexander Pruss for bringing this point to my attention.) And even though God would be the creator of spacetime, he is distinct from spacetime in a way that precludes spacetime from being wholly contained in him.

[7] Quantum superposition may allow us to say that two particles overlap in some sense, but (i) the sense of overlap here is different than that in the text; and (ii) one particle would overlap some, but not every, other particle.

The substantivalist has one more option. Rather than say spacetime is one among the many other substances, he can claim that spacetime is the only substance.[8] If spacetime is the only substance, the complaint in the previous paragraph loses any bite it has. Moreover, it now looks like substantivalism gains the upper hand since it has (far) fewer tokens of the substance type than does relationalism (assuming that the relationalist is also a metaphysical pluralist).

It might seem like I've just shot myself in the foot. The above argument from parsimony tells the substantivalist to say that there is one substance, spacetime. However, even though this version of substantivalism is the best version, it is false. Before turning to that argument, I need to make a few remarks about the relationship between scientific realism and the fundamental.

7.3 Physics and the Fundamental

Physics is a guide to what the world is like. In chapters four and five, I pointed out that we want to say that physics is a *realistic* guide to the world: our best physical models tell us what to include in the furniture of the world. As I pointed out in chapter five, that statement is not so straightforward within an Aristotelian framework. For the Aristotelian can say that there are lots of entities, including the ones affirmed by scientific models—but those entities need not be fundamental. In a flat ontology, either something exists or not; in a hierarchical ontology, either something exists or not, and if it does, either it's fundamental or not. So, when we cull from our physical theories to support our metaphysical conclusions, we need to be mindful of whether a realist attitude about scientific models is realism about what exists or about what is fundamental.

[8] See (Schaffer 2009b) for an alternate way to arrive at this conclusion. His arguments presuppose substantivalism and argue for the monistic version on the basis of this presupposition. The argument I've presented is contrastive and makes no assumption about the truth of substantivalism. That said, one can easily modify the argument in the text to get Schaffer's argument from parsimony (pp. 137–38), which is one of seven arguments he offers for the monistic version of substantivalism.

In chapter five, I said that one cannot, in general, take scientific realism to be the view that whatever entities our best scientific models commit us to are fundamental entities. But some think that physics is a special case. For instance, Ted Sider writes: "Our best physical theories are our best guide to the correct fundamental ontology and ideology" (Sider 2013, 282). *If* Sider is right, and *if* our best models for physics are ones that include spacetime, then the relationalist seems to be in trouble. But it's not clear that Sider is right. Physics does seem to carve at nature's joints better than some other scientific theories, but why it gets the privileged position of informing us about fundamental ontology while other theories don't seems to depend on several assumptions about how the sciences are ordered and what is reducible to what. While that's worth thinking about, I'm not going to concern myself with the task. It's also not clear that our best physical models include spacetime. I've already mentioned Bain's (2006) attempt to write non-relativistic electrodynamics without spacetime. Moreover, Chris Fields (2014) discusses the different metaphysical presuppositions quantum physicists make in offering a physical interpretation of a theory, and argues that this fact should lead to some hesitation in appealing to physics for metaphysical conclusions. None of this amounts to a conclusive argument against taking a realist attitude towards physics that says that our best physics tells us what is fundamental, but it does raise suspicions.

Rather than argue that physics is not a guide to what is fundamental, I am going to argue that it does not matter whether physics is a guide to the fundamental. Whether physics is a guide to the fundamental or not, substantivalism is false. Oddly enough, it turns out that the substantivalist's best best is to hold that physics is not a guide to what is fundamental. In the remainder of this section I sketch the argument against substantivalism and argue that substantivalism is false if physics is a guide to the fundamental. In the following section I argue that substantivalism is false if physics is not a guide to the fundamental.

Here's a sketch of the argument against substantivalism. Either our best physics is a guide to what is fundamental or it's not. If physics is a guide to what is fundamental, our best physics says that spacetime is not fundamental; instead, spacetime emerges from physically fundamental, changing entities; hence substantivalism is false. If physics is not a guide to what is fundamental, the substantivalist can say either that spacetime is a fundamental entity that lacks causal powers or that spacetime is the only substance.[9] Whatever he says, substantivalism is (again) false.

7.3.1 The Physical as the Fundamental

If the substantivalist wants to use physics as a guide to what is fundamental, he should use our best, most fundamental science. If our best, most fundamental science says that spacetime is fundamental, then we should infer that substantivalism is correct. The problem with this move, though, is that we don't have a best, most fundamental science. Physics is at a crossroads: quantum mechanics and general relativity (GR) are our best working theories, but they are prima facie incompatible. And, at the moment, there is no clear candidate that will replace quantum mechanics and GR or resolve the incompatibility. This suggests that, at the moment, appeals to our best physical theory to support metaphysical theses should not be taken too seriously. At best we can appeal to theories of quantum gravity, since such theories seem to be the most promising way of resolving the conflicts between GR and quantum mechanics.[10] If we do that, though, the consensus is that

---

[9] Did I not argue above that the former option is out on parsimony grounds? I did. I also noted that parsimony is not a definitive way to rule out theories. So, just in case you think my parsimony argument against spacetime as a *sui generis* entity was flawed, I'm going to argue against that version of substantivalism in a different way.

[10] And even then it's not clear how to proceed since the major research programs face difficulties reproducing quantum mechanics, GR, or both. (Thiemann 2008), (Graña 2006), and (Wallden 2010) discuss the difficulties faced by loop quantum gravity, string theory, and causal set theory, respectively, as well as ways that these theories might be able to address the difficulty.

spacetime is something that emerges.[11] If spacetime is something that emerges it isn't fundamental; and if spacetime isn't fundamental, substantivalism is false.

Perhaps a more conservatively-minded realist will accept that there's no consensus on what our best, most fundamental theory will look like. But quantum mechanics and GR are approximately true. Such a realist might say that, for this reason, we should still use GR and quantum mechanics to tell us what is fundamental. Moreover, of the two theories, GR enjoys more of a consensus on physical interpretation than does quantum mechanics. GR tells us that spacetime is a part of the furniture of the world, so spacetime is a fundamental entity.[12]

Suppose our conservative realist is right: GR is the physical theory we should use to inform us about what entities are fundamental. This does not herald a victory for the substantivalist. In fact, the substantivalist needs to go beyond GR to conclude that spacetime is a fundamental entity. I am not claiming that GR doesn't inform us about what is fundamental; what I am claiming (and will argue for) is that, in order to reach the conclusion that spacetime is fundamental, the substantivalist needs to appeal to more than just GR. And the something more is what I will address in the next section.

[11] Karen Crowther points out that a plausible principle for what makes a new theory an acceptable replacement of a predecessor entails that GR "must emerge from quantum gravity in the regime where GR is known to hold" (Crowther 2014, 11). Daniele Oriti (2014) discusses recent work in physics that "hints at the disappearance of spacetime" (S2). See also (Huggett and Wüthrich 2013) for an outline of contributions to a special issue devoted to the emergence of spacetime in quantum gravity. For specific examples of emergence in quantum gravity, (Seiberg 2006) focuses on string theory; (Ambjørn, Jurkiewicz, and Loll 2004, 2006) discuss emergence when the fundamental geometry is discrete; (Bain 2013) and (Crowther 2014) each discuss emergence for condensed matter approaches to quantum gravity.

[12] As an argument for using GR as a guide to what is fundamental, this is pretty sketchy. But I have not come across a solid case for the claim that GR is the theory we should look towards as a guide to the fundamental. In the literature there seems to be an unargued-for consensus that GR is to be preferred over quantum mechanics. This seems objectionable since it presupposes that this portion of GR's ontology will be "carried over" into our next theory. Even if this Kuhnian view of replacing one theory with another is correct—i.e. even if it's correct that we should preserve as much of the ontology of the theory (or theories) being replaced as we can—we've already seen that it's contested whether relativistic spacetime will be carried through into our next best theory; you can't simply assume that it will.

But for now, we'll see what the substantivalist can get from GR alone. Our conservative realist claims that our best models of GR include spacetime; therefore, spacetime is a fundamental entity. One way of attacking the main premise is to argue that our best models do not include spacetime. As I've mentioned previously, Bain (2006) attempts to do exactly this for non-relativistic field theories. One could attempt something similar for GR, but I will not pursue that strategy here. Let's suppose that our best models for GR do include spacetime. That still does not settle the matter in favor of substantivalism, for we can have three different models that include spacetime:

Container Substantivalism: Spacetime is an independent entity (whether a substance with causal powers or something else), and, if there are material objects, they are located in, but distinct from, spacetime;

Supersubstantivalism: Spacetime is a substance and, if there are material objects, they are identical to regions of spacetime;[13]

Spacetime Wholism: Supersubstantivalism and the thesis that spacetime is the only substance.

The difference between Supersubstantivalism and Spacetime Wholism comes down to whether you believe there are non-material substances. Spacetime Wholism says that the only possible candidate for a non-material substance is spacetime itself; Supersubstantivalism is compatible with the existence of multiple non-material substances. I assume that whatever reasons ones has for endorsing non-material substanaces are independent of the relationalism/substantivalism debate. So, for the purpose of arguing against substantivalism, Supersubstantivalism and Spacetime Wholism are one and the same thesis in what follows. Since Supersubstantivalism is talked about outside of an Aristotelian framework, I will refer only to Spacetime

[13] Sider doesn't use substance language, but given that material objects have causal powers, within an Aristotelian framework, the supersubstantivalist is committed to the view that spacetime is a substance.

Wholism to keep the Aristotelian framework in mind. On its own GR does not allow us to conclude that spacetime has causal powers and is the only entity; to arrive at that conclusion we need to go well beyond what GR says.

Our conservative realist wants to show that GR entails one of the aforementioned models of spacetime. Historically, spacetime was seen as causally inert. Spacetime neither affects nor is affected by material, changing entities. With the advent of GR, however, this view of spacetime suddenly seemed mistaken. As Sklar puts it, "the spacetime of general relativity does not have 'total immunity to causal effect' that was shared by the spacetimes appropriate to Newtonian mechanics and to special relativity" (Sklar 1974, 164). But this gets us neither the claim that spacetime has causal powers nor the claim that spacetime is the only substance.[14] So, we still have our three candidates for spacetime models (though Container Substantivalism may now be less plausible than the other two views given the remarks about causal effect).

One way that a substantivalist might argue for model Spacetime Wholism is to appeal to the field equation:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi GT_{\mu\nu}.$$

The left side of the equation (sometimes written more simply as $G_{\mu\nu}$) gives us a description of spacetime's geometry via information about the curvature of spacetime (the Rs) and the metric (g). The right side gives us a description of the energy and momentum of matter, which is encoded in $T_{\mu\nu}$. G is Newton's gravitation

[14] Though the view that spacetime does have causal powers is not uncommon, and perhaps the fact that spacetime is not immune from causal effect gives good reason to hold that it has some kind of power. We see evidence of this in Sklar's remark that "one crucial difference between the spacetime of general relativity and those we have just looked at" is that the former has causal powers while the latter do not (164). Norton (2014) echoes this by saying that the substantivalist should not hold to a weaker form of substantivalism than is given by Structured Substantivalism, the view that spacetime is a four-dimensional manifold of manifold-events with a geodesic structure and a metric: "General relativity makes it hard to view the metric field simply as part of the containing spacetime. For, in addition to spatial and temporal information, the metric field also represents the gravitational field" (S4).

constant.[15] As you would expect from the name, the field equation asserts an equality between these descriptions. Given this equality, one might be tempted to conclude that the geometry of spacetime and the distribution of matter are one and the same—especially since one can claim, as Sean Carroll does, that in GR "gravity is represented by the curvature of spacetime, *not* by a force"; and the energy and momentum of the matter "act as a source for gravity" (Carroll 2001, 14). And if they are, then we have a case for endorsing Spacetime Wholism.[16]

The problem with that argument is that equality of quantity is not identity of entity. What the field equation asserts is an equality between a measurement of the spacetime geometry (one quantity) and a measurement of the distribution of matter (another quantity). To make the move from equality of quantity to identity of entity goes well beyond what GR says.[17] In fact, defending that move does not require GR at all; whether one can make that move is wholly within the province of metaphysics. So, even if the above argument is sound, it requires going well beyond what GR says.

In sum: if you hold that physics is a guide to what's fundamental, and that quantum gravity is our best physical theory, substantivalism is in trouble; if you instead hold that it's GR that is our best physical theory, you need much more than physics to support substantivalism. And, as I'll now argue, going beyond (or even ignoring) physics still leads to the conclusion that substantivalism is false.

---

[15] For a brief introduction to the field equation see (Carroll 2001).

[16] Really, all we get is the first conjunct of Spacetime Wholism, which is Supersubstantivalism.

[17] The move from identity of entity to equality of quantity is quite easy to make in an Aristotelian framework: the equality holds because one side of an equation grounds the other. Here's a toy theory to illustrate the point. Suppose an apple is the unit from which we get the natural numbers. Suppose I have four apples in my right hand and three in my left. You might then hold that $4 + 3 = 7$ because the 4 apples in my right hand and the 3 apples in my left hand are identical to the seven apples I'm holding. But, to modify the case, even if it's true that I have four apples in each hand, so that the number of apples in my left hand equals the number of apples in my right, it's not true that the apples in my left hand are identical to the ones in my right hand.

7.4 Substantivalism is False

I've just shown that appealing to physics does not help the substantivalist argue for his view. If physics is a guide to the fundamental, either physics suggest that substantivalism is on its way out, or physics alone does not support substantivalism. Here I am going to argue directly against substantivalism. Above I ruled out Container Substantivalism on parsimony grounds and argued that Spacetime Wholism is the most plausible version of substantivalism. In this section I offer another argument against Container Substantivalism since the substantivalist may attempt to retreat to this position given that Spacetime Wholism is false.[18] (Remember, parsimony arguments are not decisive. For instance, if you think that parsimony arguments only tell you that we have no reason to say that spacetime is fundamental, rather than provide a reason to think that spacetime is not fundamental, you will want a more decisive argument against substantivalism.) The strategy here is to show that, whether spacetime has causal powers or not, substantivalism is false. I'll present the argument against Container Substantivalism first, and then argue against Spacetime Wholism.

In chapter three I offered a semantics for abstraction and construction. The intuitive picture behind those semantics is that abstraction is a way to pull things apart so we can derive properties and powers, whereas construction offers a way to put things together so we can derive more entities. Thus, grounding (or ontological dependence) relations are relations that tell us which entities are derived from which. To put a label on it:

GROUND: The grounding relations are relations of abstraction or construction.[19]

---

[18] Here's another argument against container substantivalism that I will not pursue. GR is a background-independent theory (and theories of quantum gravity strive to be background independent). To be background independent is to be free from non-dynamical structures. Container substantivalism posits a non-dynamical background object (at least for versions of the view on which spacetime lacks causal powers); so Container Substantivalism is false.

[19] This is adapted from (Schaffer 2009a, 378).

This makes plausible the following principle about causal powers and derivativeness:

CD: If x lacks causal powers, and x is concrete or contingent, then there is some entity y such that y has causal powers and x is (partially) derived from y.[20]

Here I do not take "concrete" to mean "has causal powers"; here "concrete" is meant to pay homage to the traditional distinction between concrete and abstract objects. Whatever is meant by "concrete" with respect to that distinction is what I mean by "concrete" in CD. CD is not a consequence of the semantics for abstraction and construction discussed in chapter three, so it stands in need of defense. I'll offer two ways to defend CD. The first shows that CD stands all on its own; the second is a more direct argument for the principle. I'll consider each in turn.

There are two reasons to think CD is true all on its own. The first is that CD makes our ontology simpler. CD says that a certain class of entities—those that lack causal powers and are concrete or contingent—are not fundamental entities. Fewer fundamental entities means a simpler ontology. And simpler ontologies tend to be closer to the truth (though not always: discarding all unobserved entities would simplify our ontology, but that would not be a good simplification). So, insofar as simplicity is *a* guide to the truth, we have *a* reason to hold that CD is true.

One might think that I've employed GROUND to motivate the claim that fewer fundamental entities means a simpler ontology. I haven't. In fact, the explanation runs the other way around. Because we want to cut ontological costs, we should adopt a principle like GROUND. To say that grounding relations are relations of abstraction and construction is to say that when one entity is grounded by

---

[20] I've added the second conjunct in the antecedent so that the principle does not rule out Platonic entities as fundamental, if there are any. This accommodation creates a slight complication, though, since {Socrates} is supposed to be grounded in Socrates. But if sets are necessary beings, CD does not guarantee that singleton sets for objects are derivative, and hence grounded. I don't find this much of a problem, since it seems that CD is one of several abstraction principles. If one is unconcerned about accommodating Platonic entities, one could endorse a stronger thesis: If x lacks causal powers, then there is some entity y such that y has causal powers and x is (partially) derived from y.

another, the former is derived from the latter and thus is not an ontological cost. Insofar as reducing ontological cost is a virtue of a theory, we have a reason to endorse GROUND. (And given a principle like GROUND, we should be interested in principles like CD since they offer a specific way to reduce cost; in the case of CD, the reduction comes from eliminating certain kinds of entities from the collection of fundamental entities.)

The second reason to hold that CD is true all on its own is that there seem to be no counterexamples to the principle; and it seems that there could not be any kind of normal evidence of counterexamples. If something lacks causal powers, then it does not interact with us in any of the ways entities normally interact with us. So it's hard to see how one could even come up with a convincing counterexample to CD.[21] One would first have to find an entity that lacks causal powers and is concrete or contingent (which seems hard enough, barring spacetime perhaps), and then show how that entity cannot be derived from something with causal powers.[22]

There is a more direct argument for CD. Rather than argue directly for CD, we arrive at CD through the following two princeples:

CA: If x lacks causal powers, and x is concrete or contingent, then there is some entity y such that y has causal powers and x is an abstraction from y.

AD: If there is some entity y such that y has causal powers and x is an abstraction from y, then x is (partially) derived from y.

I'll argue for these in reverse order.

---

[21] Consider also the fact that Merricks (2007) argues for the converse of CD: that there is no causal overdetermination is good reason to think that all derivative entities lack causal powers. This is evidence that there is some connection between causal powers and derivativeness. Moreover, something like CD seems quite plausible given a truthmaker view, such as that seen in (Jacobs 2011).

[22] Using spacetime as a counterexample looks like it might be an instance of what Dougherty and Pruss (2014) call anomaly mongering. They argue that, at least for the case of scientific theories and theism, apparent counterexamples (i.e. anomalies) need not lower the plausibility of the scientific theory or theism. It seems that one could attempt a similar response here.

Here's the case for AD. For the Aristotelian, abstraction involves "removing" (or disregarding) properties or powers from an entity; and removing properties and powers yields an abstract entity.[23] For instance, my character is an abstraction from me.[24] If we "remove" certain things from me, such as some of my causal powers and some other physical properties that I have, we are left with my character. Thus my character is a derivative entity; it is derived from me.[25]

In the case of my character, my character is wholly derived from me. But this need not always be the case. For instance, satyrs are fictional entities that are constructions from men and goats.[26] To derive a satyr, one needs to abstract certain properties from a man and certain properties from a goat, then conjoin them. So, satyrs are partially derived from men and partially derived from humans.[27] So, in cases of partial and whole derivation, we have good reason to endorse AD.

On an Aristotelian view of abstraction, one produces an abstraction by removing properties and powers. One easy way, then, to get abstract entities, is to remove causal powers from things that have causal powers. But this is beginning

[23] Recall the following passage from (Scaltsas 1994): "for Aristotle a substance is complex, not because it is a conglomeration of distinct abstract components like matter, form, or properties; a substance is complex because such items can be separated out by abstraction, which is a kind of division of the unified substance." Recall also that Maudlin (1990), in discussing the stripping argument of *Meatphysics* Z.3, talks about abstraction as a stripping process that is "a matter of logical abstraction, or disregarding properties" (535).

[24] Thanks to Alexander Pruss for this example and helpful discussion here.

[25] What about some kind of metaphysical causation? Talk of grounding sounds like metaphysical causation, which suggests a causal understanding of derivation. Causation may serve as a guide to dependence, since causal connections are a kind of dependence relation. However, the analogy cannot be taken too far, since, e.g., I do not cause my character; at the least, I am not the sole cause of my character. Perhaps there is some way of understanding "bringing about" that makes this approach unproblematic, but it is not obvious to me.

[26] Alternatively, one could say that the *concept* of a satyr is a construction from men and goats.

[27] This is a convenient way to explain fictional entities: we take properties of substances (which is one step of derivation) and then conjoin them (a second step of derivation) to get the fictional entity in question.

to look like CA. For anything that lacks causal powers (x), add causal powers to that thing and we have an entity from which x is abstracted. Consider characters and events. I've already mentioned how characters are abstractions from persons. Given a character, it looks like we can add in causal powers to find out to whom the character belongs.[28] The same seems true of events. Two billiard balls collide; we have the event of two billiard balls colliding. Even if events are the relata of causal relations, it seems odd to say that events themselves have causal powers. It seems better to say that objects, or substances—the billiard balls, or whatever set them in motion—have causal powers; and it is because those powers are exercised in certain ways that we have the event of two billiard balls colliding.[29] In other words, the event of two billiard balls colliding is derived from the billiard balls and their causal powers (or the causal powers of the thing(s) that set the balls in motion).

That's the intuitive idea. Here's how to apply it to other cases. The upshot of the semantics for abstraction and construction presented in chapter three is that any property we can refer to can be traced back to some fundamental entity. In other words, no entity has a property that is not also possessed by some substance (or Platonic entity, if there are any). (This is one way of seeing why the Aristotelian has difficulty accounting for uninstantiated (and underivable) properties.) Every substance has causal powers, so if we are referring to something without causal powers, whatever we are referring to is not a substance. And if what we are referring to is concrete or contingent, we are not referring to a Platonic entity. Call such an entity A. Since A is neither a substance nor a Platonic entity, the properties that A has cannot be (directly) grounded in A; A's properties must trace back to some substance(s) (or Platonic entity or entities). Moreover, since A is not a fundamental

[28] I am, of course, making some assumptions about the nature of characters and assuming that we are adding in the right kinds of causal powers.

[29] This allows us to claim directly that events depend on objects with causal powers, giving further, direct evidence for CD.

entity, it needs to be derived from fundamental entities. It is plausible that whatever entities we need to get A's properties are the entities from which A is derived. So we have a case for CA. Given CA and AD, we have CD.

7.4.1 Pointy, Gunky, or Chunky, Spacetime is not a Container

We can use CD to argue against versions of substantivalism on which spacetime does not have causal powers. One variety of Container Substantivalism is what we can call Inert Substantivalism, which is the claim that spacetime is a causally inert container. CD entails that Inert Substantivalism is false. For if spacetime is causally inert, then, by CD, there is at least one entity with causal powers on which spacetime depends. There is good reason to think that the entity or entities on which spacetime depends are changing, material entities.

Let's consider the way we get the events that comprise the spacetime manifold.[30] Recall that physicists do not use "event" in the way it is normally used. When discussing the spacetime manifold, events are best thought of as the four-dimensional analog to points in a geometric plane, and for that reason I have referred to them as "manifold-events". Here's how we arrive at manifold-events: we start with substances exercising causal powers and then abstract to get events; we then imagine these as idealized events: the particles are unextended point masses; and then we even remove the event so that we are left with a (spatiotemporal) location, a manifold-event. To account for all points of spacetime, we talk not only of actual events, but of possible ones as well.[31] What is this process if not abstraction, as described above? We start with the changing entities with causal powers; removing the causal powers from these entities gives us one level of abstraction, one which leaves us with events, as they are normally thought of. If we continue the process

---

[30] Cf. (Sklar 1974, 56).

[31] While this is standard, Field (1984) raises worries for this approach.

of abstraction, we eventually arrive at the idealized, manifold-events that comprise the spacetime manifold. Moreover, causal powers account for possible events by accounting for possible collisions. Thus, spacetime is already latent within changing entities; hence substantivalism is false.

This argument makes two key assumptions. The first is that we can derive all of the manifold-events required for a four-dimensional spacetime manifold. One unilluminating defense of this assumption is that that is just a part of the view: the manifold-events are already latent within the changing objects; so, even if there are only, say, three particles, we can still derive the spacetime manifold. A better defense will explain how we can get enough manifold-events from just a few particles, and that is what I will attempt to do now.

One worry for my view is that we might not be able to derive infinitely-many manifold events required for the spacetime manifold. If there are only, say, three particles in the universe, it's hard to imagine how we can derive so many manifold-events from so few substances. There are a few ways to ameliorate this worry, but the basic idea is this: (i) only logical or metaphysical restrictions could tell us that there is some limit to the number of manifold-events that a substance can ground; but (ii) there are no such restrictions; so, (iii) there is no problem grounding infinitely-many manifold-events from finitely-many particles. In this paragraph and the next I am intentionally vague about whether the infinitely-many is a countable or uncountable infinity. I deal with each case separately, tackling the countably-infinite case first.

The easy way out of this problem is to endorse substantivalism about space and hold that space has infinitely-many parts. If space has infinitely-many parts, then we just strip away enough content from the parts of space until we arrive at infinitely-many manifold events. Since I don't want my view to require substantivalism about space, I'll now consider a few ways to get infinitely-many manifold-events just from finitely-many particles.

I should note at the outset that the different ways of defending (i) and (ii) take a slightly different flavor than the normal line of reasoning. Typically relationalists appeal to possible locations of particles to ground all of the spatiotemporal relations required for relationalism. Here I'm not showing how to ground the relations; instead the focus is on how to ground the manifold events. As it turns out, how one can defend (i) and (ii) depends on whether particles are pointy, gunky, or chunky.[32] A particle is pointy if it has point-sized parts; gunky if it has a non-zero, finite size but is always divisible into further, smaller parts, with no ultimate smallest parts; chunky if it has a smallest non-zero size part. If particles are pointy or gunky, division is the preferred process for deriving a countable infinity of manifold-events. Since the challenge is to derive a certain quantity of manifold-events, we can take advantage of the fact that pointy or gunky particles will have infinitely-many parts.[33]

One might think something fishy has gone on here: while we have infinitely-many points, it still seems too small a number of points. After all, even infinitely dividing a particle still keeps us within the bounds of the particle, and spacetime is, presumably, larger than a particle. But I'm not after a container in which material objects are literally located; all I'm after is an *ersatz* container that (i) is grounded by concrete things and (ii) allows the ersatzer to say that those concrete things are "located in" spacetime—for that is what CD requires. Since I've provided as many particles as are needed to construct such a space, I've given you all that you need.

If particles are chunky, infinite division won't get us a countable infinity of manifold-events. Particles can be chunky in one of two ways. First, if particles are extended simples, they are chunky: the smallest non-zero size part is the particle

[32] These terms are inspired by Frank Arntzenius' discussion of matter in (Arntzenius 2012, 126).

[33] If particles are points, they will not be divisible, so using division to generate infinitely-many manifold-events won't work. Fortunately, this option can be treated in the same way as chunky particles, which I discuss below.

itself. Second, if particles are constructed from extended simples, they are chunky: the extended simples from which the particles are constructed are the smallest non-zero size parts. (If it helps, think of LEGO bricks: the first option says that particles are like the bricks; the second says that particles are like things constructed from the bricks.) On either option[34] if change is continuous and eternalism about objects is true, there is an easy way to get infinitely-many manifold-events by modifying the process of infinite division. The previous strategy appealed to spatially dividing particles to get infinitely-many manifold-events. But if eternalism is true we can temporally divide particles to get infinitely-many manifold-events. If change is continuous, there will be infinitely-many world states. Once we have world states we can strip away content until we have manifold-events. This strategy clearly depends on assumptions about eternalism and the nature of change that can be questioned, so it would be good to have another way to get infinitely-many manifold-events.

Let's not assume that change is continuous, or that eternalism is true, or that there is more than one particle. Let's also assume that (pure) sets are not fundamental: if they are, the Axiom of Infinity in ZFC set theory[35] could then be employed to give us a countably-infinite set, the members of which could be identified with manifold-events. This would both solve the problem at hand and appear to be cheating (since it would no longer matter how many particles there are). Here's what we're left to work with, then: one chunky particle all alone in the universe. In chapter three I mentioned construction relations, which ground non-fundamental entities like gaggles of geese. Sets are a kind of thing akin to a gaggle, so if construction relations allow us to ground gaggles, then they should allow us to ground sets as well. Though it might be cheating to assume that pure sets are

---

[34] And if particles are points.

[35] $\exists x[\varnothing \in x \wedge \forall y(y \in x \rightarrow S(y) \in x)]$, where $S(y) = y \cup \{y\}$.

fundamental, the same charge cannot be raised if such sets are derived. So it's worth exploring whether we can ground pure sets from a solitary, chunky particle.

Construction relations should allow for entities grounding their singletons. So, if our solitary chunky particle is called C, then C grounds $\{C\}$. C will also ground (via abstraction) a manifold event M. If construction relations allow C to ground $\{C\}$, they should also allow M to ground $\{M\}$. $\{C\}$ and $\{M\}$ are not pure sets: some member of each set is not also a set. ZFC set theory was formulated with pure sets in mind, so we should see whether we can get pure sets. And we can. We can define the empty set: $\varnothing = C \cap M = \{\,\}$. $\varnothing$ is a pure set, so we can avail ourselves of ZFC (specifically, the Axiom of Infinity) to obtain a countably-infinite set, the members of which are identified with manifold events.[36] And to reiterate a point I made above: it is not a problem that this is not a space that we can physically inhabit; all I'm concerned to show is that there is enough stuff to derive an ersatz spacetime manifold from chunky particles.

What I have shown so far is that it's possible to get a countably-infinite number of manifold-events from a finite number of particles. But one might worry that the spacetime manifold needs continuum-many manifold-events. If the spacetime manifold needs continuum-many manifold-events, then the above is insufficient to guarantee that we have enough manifold-events.

There are two ways to respond to this worry. First, one could argue that it is possible to construct continuum-many manifold-events from a countable infinity of manifold-events. If particles are pointy or gunky, and one can divide particles into continuum-many parts, then that affords an easy response. But if one cannot divide

[36] If the construction relation I gestured at in chapter is successful—or at least a similar version is—then one could do without ZFC. The principle I gestured at is a variant of the principle of universal mereological composition (UMC), and a mereology that endorse (UMC), and certain other auxiliary assumptions, can be used as a (nominalist-friendly) substitute for ZFC. (On this point, see (Lewis 1991) and (Varzi 2015).) Opting for this strategy is not uncontroversial, though: one of the auxiliary assumptions one needs posits an entity known as the null individual, an entity that is a proper part of everything. See (Hudson 2006) for a discussion of the null individual.

particles to obtain continuum-many points, there are strategies one could employ that mimic the strategies for constructing the real numbers.[37] Second, one could employ a more defensive strategy. While it is a common assumption that the spacetime manifold is continuous, it is often left at that: an unargued for assumption. One might claim that the assumption needs to be argued for. The number of manifold-events that a particle can ground is a metaphysical restriction, and metaphysical restrictions give rise to physical restrictions. For instance, if it is metaphysically impossible for iron to be transparent, then it is also physically impossible for iron to be transparent. So, if particles can only ground a countably-infinite number of manifold-events, then there can only be a countably-infinite number of manifold-events, in which case the assumption that the spacetime manifold has continuum-many manifold-events is mistaken.

The second assumption I made in using CD to argue against Container Substantivalism is that spacetime is nothing more than a four-dimensional manifold of events. But that is controversial. Earman (1989) and Norton (2014) say that spacetime just is the four-dimensional manifold. But the substantivalist might instead side with Maudlin (1993) and Hoefer (1996), holding that spacetime has more structure:

---

[37] Here are three such strategies. (For the construction of the real numbers, both strategies use the set of rational numbers. If the continuum hypothesis is true, then any countably infinite set will work for constructing the reals. If the continuum hypothesis is false, then one would need to construct the rationals from a countably infinite set in order to use either of the following strategies.) *Strategy one*: Cauchy sequences. Let M denote the countably-infinite set of manifold-events. If there is a function d on M such that (M, d) is a metric space, then (M, d) has a completion, a pair consisting of a complete metric space (M^*, d^*) and an isometry (i.e. a distance-preserving function) $f : M \to M^*$ such that $f(M)$ is dense in M^*, which is enough to (eventually) get to the real numbers. This strategy requires two assumptions: (i) that there is a pair (M, d) that is a metric space (which does not seem implausible); and (ii) that we can make use of Cauchy sequences. *Strategy two*: Dedekind cuts. This strategy partitions the rational numbers into two sets, and identifies irrational numbers with one of those sets. For instance, let $A = \{a \in \mathbb{Q} \mid a < 0 \text{ or } a^2 < 2\}$ and $B = \{b \in \mathbb{Q} \mid b > 0 \text{ or } b^2 > 2\}$. We can then identify $\sqrt{2}$ with A. *Strategy three*: The powerset of a countably infinite set will be uncountably infinite. Since we already have a countably infinite set, we can use the axiom of the powerset to generate that set's powerset, which will yield an uncountably-infinite number of manifold events.

Structured Substantivalism: Spacetime is a four-dimensional manifold of events with a geodesic structure and a metric.[38]

In other words, spacetime isn't just a collection of manifold-events: it's a collection of manifold-events with a certain amount of structure. When offering a story about how to derive continuum-many manifold-events from finitely-many particles, I paid no attention to any kind of structure that spacetime might have. If you think that Structured Substantivalism is a better version of substantivalism, that omission will raise a flag. In fact, you might even think that this more robust view of spacetime is a glimmer of hope for Container Substantivalism because there is no way to derive the extra structure from a few changing particles.

Structured Substantivalism doesn't help the substantivalist's cause, though. Structured Substantivalism talks about a manifold of events *with* a geodesic structure and metric. The most natural interpretation of "with" is that the geodesic structure and metric are somehow "built into" the manifold: spacetime is a four-dimensional manifold and that manifold has a certain intrinsic structure.[39] Suppose the geodesic structure and metric are somehow "built into" the manifold, and that we have spelled out what this means. (Though this is a questionable assumption since it suggests that the geometry of spacetime can be specified independent of the distribution of matter. As we saw above, that is not the case, so this is a fairly generous point to grant.) CD tells us that any causally inert entity is not fundamental,

[38] This is what Sklar (1974, 62) says for the spacetime of general relativity. A neo-Newtonian view would talk about an affine structure instead of a geodesic structure.

[39] Another interpretation is that Structured Substantivalism says that the manifold of events has a certain structure, but the structure of the manifold is not intrinsic to the maniofld. If that's the case, Container Substantivalism fares no better, since the requisite structure may be given by the material objects. In other words, we may be able to derive both the manifold and the structure from the material objects. In fact, that is one way of reading the field equation: spacetime has the geometric structure it does *because* the matter has the energy and momentum that it does. If that's all that "with" signals, the above arguments still stand. So, if Structured Substantivalism is supposed to offer a better version of Container Substantivalism, the requisite structure of the manifold will have to come from the manifold itself; i.e. it must be false that spacetime has the curvature and metric it does because the matter has the momentum and energy that it does.

which means that even the more robust spacetime posited by Structured Substantivalism is also a derived entity. But above I did not mention anything about structure when I offered a story for how to derive a spacetime manifold from three particles. So, the proponent of Structured Substantivalism might contend that, unless the relationalist can derive a spacetime manifold with a geodesic structure and metric, the relationalist cannot rule out Structured Substantivalism simply by appealing to CD. That is, the Structured Substantivalist might think that Structured Substantivalism offers a counterexample to CD.

The short way of dealing with this complaint is to refer the reader to chapter five. In that chapter I showed how one can derive the temporal order and the metric from changing entities. Given the way the derivation of the metric takes place, it looks like I too can claim that the metric is "built into" the four-dimensional manifold. If the substantivalist objects, then it is up to him to do one of two things: (i) specify further what it means for the metric to be "built into" the four-dimensional manifold in a way that does not imply that the geometry of spacetime is determined independently of the energy and momentum of matter; or (ii) show why it is not a violation of the spirit of GR to have the geometry of spacetime specified independently of the energy and momentum of matter.

That's the argument against Inert Substantivalism. Remember, Inert Substantivalism is one of two ways the substantivalist can fill out her view of spacetime: either spacetime has causal powers or not. Given the argument against Inert Substantivalism, the substantivalist's remaining option is to say that spacetime has causal powers. Above I argued that, if spacetime has causal powers, Spacetime Wholism is the best version of substantivalism. I'll now argue against Spacetime Wholism.

7.4.2 Holes and Wholism

Spacetime Wholism combines supersubstantivalism and substance monism. Supersubstantivalism, recall, is the view that spacetime is a substance and material objects are identical to regions of spacetime. Substance monism is the thesis that there is only one substance.[40] I'm going to rehearse some of the details of a monist metaphysic, pointing out some consequences that might give one reason to reject Spacetime Wholism. Those reasons for rejecting Spacetime Wholism depend on other metaphysical commitments that one has, so they are not the strongest reasons to reject Spacetime Wholism. So, after presenting those reasons, I will argue directly against Spacetime Wholism.

The substance monist holds that there is only one substance. Substance monism is contrasted with substance pluralism, which is the view that there is more than one substance. The kind of monism relevant to the current discussion is a monism on which the one substance is the entire cosmos, often called "The One" or "The Whole". This kind of monist does not deny that there is more than one thing; what she denies is that the entire cosmos is made up of more than one substance. The monist holds that the plurality of things we experience are parts of The Whole, and that The Whole grounds its parts. (Likewise, the pluralist does not deny the existence of the whole; he instead says that the whole is grounded in its parts.) In other words, the plurality of things that we experience are abstractions from, and thus ontologically dependent on, The Whole. So, the monist can claim that there is more than one thing, provided that derivative entities and non-substances count as things.

One can see how substance monism and supersubstantivalism are a natural fit. If spacetime is the one substance, then every region of spacetime is a derivative

---

[40] Though the view fell out of favor in the 20$^{\text{th}}$ century, recently monism has been defended most prominently in (Schaffer 2010a, 2010b). See also (Tallant 2015).

entity, and some of these regions are material objects. If spacetime just is The Whole, we have a clean account of our experience of the plurality of things. So, if monism is an attractive thesis for you, Spacetime Wholism is as well.

Before arguing directly against Spacetime Wholism, I want to mention two consequences of Spacetime Wholism that might lead one to reject the view. The first consequence of Spacetime Wholism is that eternalism about objects is true.[41] Physics requires that spacetime is four-dimensional. If spacetime just is The Whole, then The Whole is also four-dimensional. Since material objects are identical to regions of spacetime, then, provided that there are material objects, those objects are equally real even though they occupy disjoint temporal locations. But to say that material objects are equally real even though they occupy disjoint temporal locations just is to say that eternalism is true.[42] So, if you reject eternalism, you should say that spacetime is not The Whole. The second consequence of Spacetime Wholism takes the form of a dilemma. Supersubstantivalism entails that every material object is a region of spacetime. While this does not imply that spacetime itself is a material object, it would be odd if spacetime were not material: whence do we derive materiality from, if not The Whole? If The Whole is material, and it is the only substance, then every substance is material.[43] This conclusion is troublesome,

[41] See (Schaffer 2009b, 135) for a different argument for the same conclusion.

[42] One could resist this conclusion by adopting something akin to an eternalist A-theory. The eternalist A-theorist endorses eternalism about objects but claims that only one time is metaphysically privileged. This view is often referred to as the "moving-spotlight view". Another way to think of this view is that it gets you four-dimensionalism with a without a full-blooded eternalist thesis. (See (Sullivan 2012) and (Zimmerman 2005) for discussion of this kind of view.) The Spacetime Wholist could maintain, in similar fashion, that there is only ever one hypersurface of The Whole that has material objects. One might still complain that, even though material objects are not fundamental, The Whole, which is fundamental, is still four-dimensional; and, given the next objection, one might also complain that The Whole is in fact a four-dimensional material object.

[43] Further support for this comes from the way that Schaffer (2014a) introduces monism: the monist claims that there is one *concrete* object. "Concrete" is a notoriously ambiguous word, as we've seen; from the best that I can tell, though, Schaffer uses "concrete" to mean something like "material".

especially for theists who hold that God is a substance (or that there are other non-material substances such as angels).[44] If, on the other hand, spacetime is not material, then it looks like the Spacetime Wholist is committed to some kind of idealism or Spinozism.[45] So, the Spacetime Wholist appears to be committed to either idealism or materialism. These two consequences of Spacetime Wholism are not fatal, for they rely on prior metaphysical commitments. But there is another way to argue against Spacetime Wholism that does not require such commitments.

The direct argument against Spacetime Wholism is the Hole Argument. I am going to rehearse the Hole Argument and point out why its success is devastating for substantivalism. I'll then consider one way that the spacetime wholist could respond to the Hole Argument. In discussing this response, another way of arguing against substantivalism will become clear.

The Hole Argument was originally articulated by Einstein (1914) in the context of GR. In that version of the argument, Einstein was considering neighborhoods of spacetime that were devoid of matter; i.e. regions of spacetime that were holes. The version I present is a generalization of Einstein's argument that was developed by Earman and Norton (1987). Earman and Norton's version is a generalization of Einstein's argument because their argument targets any local spacetime theory, not just relativity theory.[46] A local spacetime theory is a theory whose models contain a differential manifold and a number of geometric objects defined over that manifold.

---

[44] The theist could hold that spacetime is the only material substance and that there are other non-material substances, but that would go against the spirit of monism.

[45] Here's one way to arrive at this. One way of holding that spacetime is not material even though there are material objects is to say that x is a material object iff it is a (proper) region of spacetime. Apart from the consequence mentioned in the text, this also has another consequence: any empty regions of spacetime are material objects.

[46] Arntzenius (2012) claims that the Hole Argument is really just an updated version of the Leibniz-shift arguments.

In what follows I use the presentation of the Hole Argument found in (Norton 1994, 2014).

There are three main claims that underwrite the Hole Argument. (i) For any local spacetime theory we can change the geometrical structure of the spacetime manifold without also changing invariant properties of the manifold. (ii) The substantivalist is committed to the claim that spacetime manifolds that differ with respect to geometric structure represent distinct physical possibilities—even if the invariant properties are the same in both manifolds. But (iii) spacetime manifolds represent distinct possibilities only if the manifolds differ in their invariant properties.

No one disputes (i). In local spacetime theories, active general covariance is a feature of spacetime that allows us "to spread geometrical structures like metrical fields over the manifold in as many different ways as there are coordinate transformations" (Norton 2014, S2). The phrase "in as many different ways as there are coordinate transformations" is a bit imprecise. But we can make it more precise by talking about a specific kind of coordinate transformation, which is called a hole transformation. A hole transformation is a kind of diffeomorphism. Specifically, a hole transformation is a function h such that (i) outside of some arbitrary neighborhood of the manifold M, h is the identity function and (ii) h smoothly differs from the identity function within the arbitrary neighborhood of M. The arbitrary neighborhood is the Hole. Given a model for a local spacetime theory, there are collections of diffeomorphic copies of that model. So, there are collections of models that share all invariant properties yet differ with respect to geometric structure.

With these terms we can write the Hole Argument a bit more precisely. For the sake of concreteness, I'll use GR in the proceeding argument. A model for GR consists of a triple $\langle M, g, T \rangle$, where M is a four-dimensional manifold, g is a tensor that tells us the geometry of spacetime, and T is the stress-energy tensor, which describes the distribution of matter. T and g are related by the field equation, which was discussed above.

(1) Spacetime admits hole transformations.

(2) If spacetime admits hole transformations, then for any model $\langle M, g, T\rangle$ and any hole transformation h, $\langle h(M), h(g), h(T)\rangle$ is a diffeomorphic copy of $\langle M, g, T\rangle$ (i.e. there are collections of diffeomorphic models).

(3) If there are collections of diffeomorphic models, each member of this collection represents the same physical situation.

(4) If substantivalism is true, collections of diffeomorphic models do not represent the same physical situation.

(5) Therefore, substantivalism is not true.

If no one disputes 1, the success of the Hole Argument comes down to 3 and 4 since 2 is just a consequence of admitting hole transformations. Most substantivalists who discuss the Hole Argument seem to grant 3 but try to find a case against 4. But it's worth saying a few words about 3.

Hole transformations preserve invariant properties. That is, diffeomorphic models agree on all invariant properties such as time elapsed along a worldline and distance along spatial curves (when each are measured by the interval function, which is a part of the geometry of the manifold). (By contrast, non-invariant properties are those such as the point that is the origin of the coordinate system. Invariant properties do not depend on the coordinate system we choose, non-invariant properties do.) This is important, for it is the start of the case for 3 (which is commonly called "Leibniz Equivalence"). Norton points out that "All observables can be reduced to invariants" (Norton 2014, S3.2). If all observables are reducible to invariants, and diffeomorphic models agree on invariants, then diffeomorphic models agree on all observables. In other words, differomorphic models are observationally indistinguishable. To conclude 3 we need the additional claim that if diffeomorphic models agree on all observables, then diffeomorphic models represent the same physical system.[47]

Finally we come to 4. The defense of 4 brings out a salient difference between the target of the Hole Argument and Spacetime Wholism. The Hole Argument looks like an argument against Container Substantivalism. Container Substantivalism, recall, is the thesis that the spacetime manifold (M) is an independent entity that serves as a container for material objects. This is clearly a different thesis than Spacetime Wholism. So, even if one can defend 4 for Container Substantivalism, one might think that this has been a wild goose chase as a case against Spacetime Wholism.

Except it hasn't. The argument for 4 in the case of manifold substantivalism is this:

> The manifold substantivalist must insist that the rearrangement of spacetime structures against the background of the spacetime manifold leads to a structure that represents a different physical situation. Since the carry along under diffeomorphism effects just such a rearrangement, the manifold substantivalist must insist that a model of a spacetime theory and a (non-identical) diffeomorphic copy of it represent different physical situations. (Norton 1994, 59)

In his (2014), Norton provides a helpful example to defend the first sentence: "imagine that a galaxy passes through some [manifold-]event E in the hole. After the hole transformation, this galaxy might not pass through that [manifold-]event." By rearranging, say, the metric structure, the hole transformation forces the galaxy to take a different path through the manifold in order to preserve all of the (invariant) distances between other objects. Even if the galaxy travelled through E before the

---

[47] For one defense of this, see (Norton 1987). What keeps this last claim from being objectionably positivistic is the claim that the diffeomorphic models *represent* the same physical system. Another reason to endorse Leibniz Equivalence is that, if we deny it, "the fullest specification of all the fields outside The Hole will not enable the theory to determine how the model will develop into The Hole, *no matter how small The Hole is in spatial and temporal extent*" (Norton 1994, 58). This kind of indeterminism in a theory like GR is objectionable; so, we should accept Leibniz Equivalence.

hole transformation, the world line of the galaxy needs to be mapped onto a different set of manifold-events after the transformation in order to preserve invariant properties. Norton then concludes that, "For the manifold substantivalist, this must be a matter of objective physical fact: either the galaxy passes through E or not. The two distributions represent two physically distinct possibilities" (Norton 2014, S5).

For the container substantivalist, a deterministic theory is one on which the galaxy passes through E or not. The spacetime wholist is also a supersubstantivalist, so the language of a galaxy "passing through" a manifold-event is at best metaphorical. The spacetime wholist can more accurately state determinism in terms of identity: the galaxy is either identical to E or not. Furthermore, the galaxy in a diffeomorphic copy of the original model must be identical to some manifold-event other than E in order to preserve invariant properties. E is a manifold-event, and it just so happens that the galaxy is identical to E before the hole transformation. But, for the same reasons given in the previous paragraph, the hole transformation forces the galaxy to take a different path through the manifold, which, for the spacetime wholist, means that the galaxy's world-line is identical to one set of manifold-events before the transformation and identical to a different set after the transformation. With this minor adjustment, we can run the argument as before.

There have been many responses to the Hole Argument. One that seems especially plausible is to claim that regions of spacetime do not have all of their properties essentially. One version of this response is given by Carolyn Brighouse (1994).[48] She (correctly) notes that the case for 4 "hinges on whether or not a substantivalist is committed to a particular way of identifying spacetime points [or regions] across possible worlds" (121). She proposes a version of Container Substantivalism that does not require the denial of Leibniz Equivalence. The core of her view is that

[48] See (Arntzenius 2012, S5.12) for a similar kind of response to the Hole Argument.

spacetime regions are individuated across possible worlds according to qualitative similarity (Brighouse 1994, 122). So, at least for the container view, collections of diffeomorphic copies are not sufficiently qualitatively different from one another to yield distinct physical possibilities. Adapting this for Spacetime Wholism appears to offer a way out of my argument.[49] While a nice response to the Hole Argument, it is not one that the spacetime wholist can endorse. In fact, it looks as if the spacetime wholist must accept the claim that regions of spacetime have a number of properties essentially, and that, as I'll show, leads to an unattractive consequence.

Suppose we take Brighouse's suggestion that regions are individuated by qualitative similarity. One way of understanding this is by way of comparison with counterpart theory for individuals. According to the counterpart theorist, Pumpkin the cat exists only in this world. In other worlds there are individuals very much like Pumpkin, but those individuals are not Pumpkin; instead, those individuals are Pumpkin's counterparts. When we want to know what sorts of things Pumpkin could have done or what Pumpkin could have been like, we look to those counterparts to tell us the answer. Brighouse suggests that something similar can be used to get out of the Hole Argument.

While counterpart theory has its problems, I'm not going to worry about them. In fact, I'll grant that the substantivalist can get out of the Hole Argument by appealing to something like counterpart theory when spacetime and individuals are kept separate. But what I will argue for is that when we conjoin individuals and spacetime in the manner prescribed by Spacetime Wholism, trouble ensues.

[49] Arntzenius (2012, SS5.12–5.13) seems to think that this is not even worth arguing for. After presenting his version of Brighouse's view, he has a short section on supersubstantivalism that, more or less, describes the view and says it has a number of advantages over Container Substantivalism. He does not give any thought to whether Supersubstantivalism will be able to adapt the arguments he gave earlier in the chapter. (Though he does say that he has only given *prima facie* reasons for favoring Supersubstantivalism over other kinds of substantivalism.)

One question left open by counterpart theory is that is doesn't tell us whether individuals have certain properties essentially. Without specifying what is essential to what, it seems safe to say that Pumpkin the cat could not have been a brick, just I could not have been a poached egg. It also seems safe to say that I could not have been a cat, Pumpkin could not have been a human, and neither of us could have been immaterial. If any of these claims strike you as plausible, Spacetime Wholism is not for you.

Say that a world is empty just in case it has no material objects and likewise for a region of spacetime. Either there are empty worlds or there aren't. Suppose there are empty worlds and consider a (non-empty) region d in the actual world. Could d have been empty? It is tempting to say that the answer is yes. But if I am identical to d, that is a troubling conclusion, for it suggests that I could have been immaterial. In an empty world, some region is d's counterpart; if empty regions are immaterial, then in that world so am I. Now suppose there are no empty worlds and consider the region p, which is identical to Pumpkin. Even though there are no empty worlds, there can still be empty regions within a world. Could p have been empty? Intuitively, it seems that p could have been empty. But if p were an empty region, then Pumpkin would be immaterial. But it seems that Pumpkin cannot be immaterial; so p cannot be empty. Suppose further that there is a world with one material object, say a brick. The region p is most similar to the region identical to the brick, which implies that Pumpkin could have been a brick.

There's a lot going on in the previous paragraph, but the cases follow a general recipe. I started by noting that restrictions on the modal properties of individuals are not in perfect correspondence with restrictions on the modal properties of regions of spacetime. For instance, if a region of spacetime actually instantiates personhood, there should be worlds in which that region does not instantiate personhood—even though an individual that is a person in this world should be a person in every world.

But individuals (insofar as they are material objects) are identical to regions of spacetime. If you take on board the attractive assumption that identity is necessary, then there are two ways to get into trouble. First, if we focus on the fact that regions of spacetime need not instantiate materiality or personhood, then we can find worlds in which I am a poached egg or immaterial since I am identical to some region of spacetime r in this world but r is identical to a poached egg or something immaterial in another world. Moreover, if regions of spacetime have counterparts in every world, then I am essential to the existence of the cosmos since the region I am identical to exists in every world. But that's absurd: I'm not essential to the existence of the cosmos! Second, if we focus on the modal properties of individuals, then if r is a region that is identical to an individual who is essentially a material object (or a person), then r is essentially a material object (or a person).

One might try to work around these difficulties by weakening Spacetime Wholism. Rather than say material objects are identical to regions of spacetime, one might instead say that material objects are grounded in but not identical to regions of spacetime.[50] Call this view Weakened Spacetime Wholism (WSW). WSW avoids the above argument, but it has its own problems. Note that WSW requires that no material objects—humans included—are fundamental entities. This means that material objects are constructed from the properties and relations instantiated by regions of spacetime. For instance, if, as I gestured at in chapter three, a modified version of the principle of universal mereological composition is a viable construction relation, then material objects are fusions. This leads to three problems for WSW. The first problem is that something like the bundle theory is true for material ob-

[50] Thanks to Alexander Pruss for pushing this point. It is worth noting, though, that Schaffer (arguably the most prominent defender of Spacetime Wholism) endorses the stronger version of Spacetime Wholism: "I will be defending the identity view, which is the version of monism that identifies every spacetime region with a material object. On this view there is no distinction between the container and the contained" (Schaffer 2009b, 133).

jects, and there are a number of problems with the bundle theory.[51] Moreover, it would be odd if WSW denied self-identity. So, even if WSW is true, I am still identical to myself. But if I am nothing more than, say, a fusion of properties, and if identity is necessary, then I am, necessarily, identical to myself, i.e. to that fusion of properties. And this is the second problem: I seem to have a number of properties contingently—*having blonde hair*, *having two arms*, etc.—but WSW suggests that I have all of those properties necessarily: so, either I exist in a world just as I am in this one or not at all. While I am not essential to the existence of the cosmos, I would like to think that my existence is not such a fragile matter. One way out of this problem leads to the third. The Weak-Spacetime-Wholist could claim that I have been unfair in my use of the grounding semantics, for part and parcel of those semantics is that functionalism is the appropriate attitude to have towards derivative entities. So, what fusion of properties is me depends on what roles need to be filled. This might allow for enough variance in what fusion is identical to me so that some of my properties are contingent. But then I am an indeterminate individual: who or what I am depends on what roles need to be filled. This cries out for an explanation. For the only way around this very odd consequence is an alternative semantics for grounding.

Perhaps the Spacetime Wholist has a way around these difficulties. One way is to bite the bullet and sacrifice either our intuitions about the modal properties of individuals or our intuitions about the modal properties of spacetime. Neither of these are attractive options, though they do seem to be the substantivalist's best bet. But if that's the case, so much the worse for Spacetime Wholism, and so much the worse for substantivalism.

[51] See (Loux 1997) for an overview of the problems. See also (Wildman 2015, 1420)

7.5 Conclusion

I've argued that substantivalism is false. I opened this chapter by arguing that the best version of substantivalism maintains that spacetime is a fundamental entity, that spacetime is the only substance, and that material objects are identical to regions of spacetime. I then argued that, whether we take physics as a guide to what is fundamental or we don't, substantivalism is false.

CHAPTER EIGHT

Conclusion

This dissertation has defended an Aristotelian, relational view of time. The view of time that I put forth maintains that time is a world-state system ordered by the axioms of tense logic. World-state systems are collections of world states, which are sentences that tell us everything that is going on when they are true. As I argued in chapter five, this view is able to account for the folk theory of time, can make sense of viable solutions to the problem of change, and has the resources to express our best physical theories in a way that preserves theoretical unity, which in this case means that relationalism is able to state the connection between predicates about temporal distance. Moreover, the view meets the criteria discussed in chapter two: it maintains that time is a dependent (non-fundamental) entity; implies that the direction of time is reducible to the changes that substances undergo; and implies that reductionism about tense is false since tensed statement are a more accurate description of the world than are tenseless ones, i.e. tense is an ineliminable aspect of reality.

Given that time is not a fundamental entity, world states are not the only candidate for times. For, as I argued in chapter three, one should adopt a functionalist attitude when dealing with non-fundamental entities. The functionalist is concerned more with the roles that some entity is supposed to play than saying what some particularly entity is. Thus, when it comes to time, the relationalist is first concerned with finding out what roles need to played in order for some entity to be called "time"; she is then concerned with finding (via abstraction or construction) some entity that plays those roles. So, as long as there are other candidates that can play the role of times, the view that times are world states is not the only view of times the relationalist can endorse.

While there are likely to be other views of times, that does not mean that every alternative is a good one. In chapter six I discussed how various alternatives were not as good of candidates for times as are world states. In discussing alternate candidates for times, we saw two further restrictions on which entities can play the role of times. The first restriction is that times cannot be pure temporal locations. The reason for this is that, if times are pure temporal locations, we then need something else to tell us what goes on at each location, and the most promising views appear to have unpalatable consequences or require a stance on eternalism. Since it's best to avoid unpalatable consequences, and (as I argued in chapter two) a view of time does not require a stance on eternalism, the relationalist should not say that times are pure temporal locations. The second restriction is that any view of times should be able to make sense of claims such as "I did not go running yesterday, but I could have". As discussed in chapter six, most views on which times are identical to some abstractum cannot account for such truths. I offered one way out of this predicament and showed how the view that times are world states is able to take that way.

Showing that relationalism is a viable view of time is a significant conclusion, since current orthodoxy suggests otherwise. What is also significant is that, given an Aristotelian ontology, there is reason to reject substantivalism about time and about spacetime. Currently, in the literature the (often unspoken) consensus is that substantivalism is true. If for no other reason, the main conclusion of my dissertation shows that current orthodoxy about the ontology of time (and spacetime) is mistaken. (Granted, this conclusion depends on an ontological framework that not everybody accepts. But arguing that an Aristotelian ontology is the right ontology is a project for another day.) As I pointed out in chapter seven, substantivalism is not as well supported by physics as most substantivalists believe. For if one takes physics as a guide to the fundamental, it seems as if substantivalism will not be implied by the models of quantum gravity, which seems to be our next best physical theory. On the other hand, even if we are conservative about physics and still use General Relativity (GR) to defend substantivalism, it turns out that one needs to go well beyond what GR says to arrive at the conclusion that spacetime is a fundamental entity. This opens up the substantivalist to an attack on metaphysical grounds. While I employed the Hole Argument to launch this attack, the Hole Argument was a convenient way to bring out deeper problems with substantivalism.

The main aim of this dissertation was to defend an Aristotelian, relational view of time. In the process of defending such a view, there were a few points that had to be passed over or dealt with in too short a manner. I want to close by considering two such points, both of which are related to the discussion of the Aristotelian framework in chapter three, and suggesting how future research on these topics might proceed.

The first topic that bears further reflection is functionalism. While functionalism is not a new attitude, how it appears in the philosophy of time is worth further reflection. The discussion of substantivity in chapter three made a case that the relationalist should also be a functionalist. Since time is not a fundamental entity, we should first reflect on the roles that time needs to play, and then go search for (which, in this case means abstract or construct) entities that are candidates to play those roles. It seems clear that substantivalism does not imply functionalism about spacetime, but it is worth considering whether one could hold both views. For instance, contemporary physics maintains that there are several, distinct fields. As Carlo Rovelli noted, it is sheer convenience that we chose the gravitational field to be spacetime. This suggests a functionalist attitude about which field plays the role of spacetime. This would not contradict the claim I made in chapter three that it is only the substantivalist who faces a substantive question about whether time or spacetime is fundamental. Even though the debate over which field is spacetime may be nonsubstantive, deciding whether it is time or spacetime that is the fundamental entity is still substantive, since the roles played by each entity are distinct. And while I do not suspect that functionalism will save substantivalism from the arguments put forth in chapter seven, it is an avenue of research the substantivalist may wish to pursue—if functionalism is consistent with the spirit of substantivalism.

The second topic that would benefit from further work is the discussion of grounding. As noted in chapter three, I considered semantics for only one kind of abstraction. While this kind of abstraction is highly useful (since it gives us kinds without a commitment to Platonic entities), it is likely not the only kind of abstraction. Determining what other varieties of abstraction there are would be useful for deciding what other entities the Aristotelian can get at no ontological cost from abstraction. There is also the question of what construction looks like for the Aristotelian. I gestured at one construction principle, which was based on the principle of universal mereological composition. I noted that it is unlikely that one could use the quantifiers defined for abstraction to state a construction principle. In fact, it is likely that the Aristotelian will need to define another kind of quantifier to account for constructed entities. This is significant, for it goes against the consensus that there is a univocal notion of grounding. What's more, it looks like whether the Aristotelian needs more than one kind of grounding relation depends on whether the Aristotelian is a substance monist or a substance pluralist. This has not been considered in the literature, so further research into the topic is likely to make novel contributions to the grounding literature.

BIBLIOGRAPHY

Adams, Robert M. 1986. “Time and Thisness.” *Midwest Studies in Philosophy* 11 (1): 315–329.

Ambjørn, J., J. Jurkiewicz, and R. Loll. 2004. “Emergence of a 4D World from Causal Quantum Gravity.” eprint: hep-th/0404156. http://arxiv.org/abs/hep-th/0404156v4.

———. 2006. “Quantum Gravity, or The Art of Building Spacetime.” eprint: hep-th/0604212. http://arxiv.org/abs/hep-th/0604212v1.

Annas, Julia. 1975. “Aristotle, Number, and Time.” *The Philosophical Quarterly* 25 (99): 97–113.

Aristotle. 1984. *The Complete Works of Aristotle.* Edited by Jonathan Barnes. Vol. 1 & 2. Princeton: Princeton University Press.

Armstrong, David M. 1997. *A World of States of Affairs.* Cambridge: Cambridge University Press.

Arntzenius, Frank. 2012. *Space, Time, and Stuff.* Oxford: Oxford University Press.

Bain, Jonathan. 2006. “Spacetime Structuralism.” In *The Ontology of Spacetime,* edited by Dennis Dieks, 1:37–65. Amsterdam: Elsevier.

———. 2013. “The emergence of spacetime in condensed matter approaches to quantum gravity.” *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44 (3): 338–345. doi:doi:10.1016/j.shpsb.2012.05.001.

Bardon, Adrian. 2013. *A Brief History of the Philosophy of Time.* Oxford University Press.

Baron, Samuel. 2014. “The Priority of the Now.” *Pacific Philosophical Quarterly* 96 (3): 325–348.

Baron, Samuel, and Kristie Miller. 2013. “Characterising Eternalism.” In *New Papers on the Present,* edited by G. Torrengo, Kristie Miller, and R. Ciuini. Philosophia Verlag.

———. 2014. “What is temporal error theory?” *Philosophical Studies.* doi:10.1007/s11098-014-0419-4.

Beer, Michelle. 1988. "Temporal Indexicals and the Passage of Time." *The Philosophical Quarterly* 38 (151): 158–164.

Belnap, Nuel, and Mitchell Green. 1994. "Indeterminism and the Thin Red Line" [in English]. *Philosophical Perspectives* 8: ISSN: 15208583. http://www.jstor.org/stable/2214178.

Belot, Gordon. 2011. *Geometric Possibility.* New York: Oxford University Press.

Benacerraf, Paul. 1965. "What Numbers Could Not Be." *The Philosophical Review* 74 (1): 47–73.

Bennett, Karen. 2011. "Construction Area (No Hard Hat Required)." *Philosophical Studies* 154:79–104. doi:10.1007/s11098-011-9703-8.

Bigelow, John. 1996. "Presentism and Properties." *Philosophical Perspectives* 10.

Bourne, Craig. 2006. *A Future For Presentism.* New York: Oxford University Press.

Brighouse, Carolyn. 1994. "Spacetime and Holes." *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* One:117–125.

Broad, C.D. 1923. *Scientific Thought.* London: Routledge / Kegan Paul.

———. 1938. *Examination of McTaggart's Philosophy.* Vol. II. I. Cambridge: Cambridge University Press.

Carroll, Sean M. 2001. "A No-Nonsense Introduction to General Relativity." http://preposterousuniverse.com/grnotes/grtinypdf.pdf.

Chalmers, David J. 2011. "Verbal Disputes." *Philosophical Review* 120 (4): 515–566.

Chisholm, Roderick. 1976. *Person and Object.* Chicago: Open Court.

———. 1979. "Objects and Persons: Revisions and Replies." *Grazer Philosophische Studien* 7/8:317–388.

———. 1990. "Events Without Times." *Noûs* 24:413–428.

Chmielewski, Tom. 2015. "Jet Lag Is Worse on Mars." *The Atlantic* (February). www.theatlantic.com/technology/archive/2015/02/jet-lag-is-worse-on-mars/386033.

Correia, Fabrice. 2005. *Existential Dependence and Cognate Notions.* Munich: Philosophia Verlag.

Craig, William Lane. 2000a. *The Tensed Theory of Time.* Dordrecht: Kluwer Academic Publishers.

———. 2000b. *The Tenseless Theory of Time.* Dordrecht: Kluwer Academic Publishers.

Crisp, Thomas M. 2003. "Presentism." In *The Oxford Handbook of Metaphysics,* edited by M. Loux and Dean Zimmerman, 211–45. Oxford: Oxford University Press.

———. 2007. "Presentism and the Grounding Objection." *Noûs* 41 (1): 90–109.

Crowther, Karen. 2014. *Appearing Out of Nowhere: The Emergence of Spacetime in Quantum Gravity.* PhD diss., The University of Sydney.

Curd, Patricia, ed. 1996. *A Presocratics Reader.* Translated by Richard D. McKirahan. Hackett.

Davey, Kevin, and Rob Clifton. 2001. "Insufficient Reason in the 'New Cosmological Argument'." *Religious Studies* 37 (4): 485–490.

Davidson, Matthew. 2003. "Presentism and the Non-Present." *Philosophical Studies* 113 (1): 77–92.

———. 2004. "Critical Notice of Sider 2001." *Philosophical Books* 45 (1): 17–33.

Dougherty, Trent, and Alexander R. Pruss. 2014. "Evil and the Problem of Anomaly." In *Oxford Studies in Philosophy of Religion,* edited by Jonathan L. Kvanvig, vol. 5. Oxford: Oxford University Press. doi:10.1093/acprof:oso/9780198704768.003.0003.

Earman, John. 1989. *World Enough and Space-Time: Absolute Versus Relational Theories of Space and Time.* Cambridge, MA: MIT Bradford.

Earman, John, and John Norton. 1987. "What Price Spacetime Substantivalism? The Hole Story." *British Journal for the Philosophy of Science* 38:515–525.

Einstein, Albert. 1914. "Die formale Grundlage der allgemeinen Relativitaetstheorie." *Preuss. Akad. der Wiss., Sitz:* 1013–1085.

———. 1920. *Relativity: The Special and General Theory.* New York: Henry Holt.

Field, Hartry. 1980. *Science Without Numbers.* Blackwell Publishing.

———. 1984. "Can We Dispense With Space-Time?" *Proceedings of the Biennial Meeting of the Philosophy of Science Association* 2.

Fields, Chris. 2014. "A Physics-Based Metaphysics is a Metaphysics-Based Metaphysics." *Acta Analytica* 29 (2): 131–148. doi:10.1007/s12136-013-0204-6.

Findlay, J.N. 1941. "Time: A Treatment of Some Puzzles." *Australasian Journal of Philosophy* 19 (3): 216–235.

Fine, Kit. 1991. "The Study of Ontology." *Noûs* 25 (3): 263–294.

———. 2005. *Modality and Tense.* Oxford: Clarendon Press.

———. 2010. "Towards a Theory of Parts." *Journal of Philosophy* 107 (11): 559–589.

———. 2012. "Guide to Ground." In *Metaphysical Grounding: Understanding the Structure of Reality,* edited by Fabrice Correia and Benjamin Schnieder. Cambridge, MA: Cambridge University Press.

———. 2013. "Fundamental Truth and Fundamental Terms." *Philosophy and Phenomenological Research* 87 (3): 725–732. doi:10.1111/phpr.12072.

Friedman, Michael. 1983. *Foundations of Space-Time Theories: Relativistic Physics and Philosophy of Science.* Princeton: Princeton University Press.

Furley, David J. 1976. "Aristotle and the Atomists on Motion in a Void." In *Motion and Time, Space and Matter,* edited by Peter K. Machamer and Robert G. Turnbull, 83–100. Columbus: Ohio State University Press.

Gale, Richard M, and Alexander R. Pruss. 1999. "A New Cosmological Argument." *Religious Studies* 35 (4): 461–476.

———. 2002. "A response to Oppy, and to Davey and Clifton." *Religious Studies* 38 (1): 89–99.

Geach, Peter. 1972. "Some Problems About Time." Chap. 302–318 in *Logic Matters.* Berkeley / Los Angeles: University of California Press.

Geach, Peter Thomas. 1949. "*Nicolaus of Autrecourt. A Study in 14th Century Thought.* by Julius Rudolph Weinberg." *Mind* 58 (230): 238–245.

———. 1955. "*Stoic Logic* by Beson Mates." *The Philosophical Review* 64 (1): 143–145.

Geroch, Robert. 1978. *General Relativity From A to B.* Chicago / London: The University of Chicago Press.

Goranko, Valentin, and Antony Galton. 2015. "Temporl Logic." In *The Stanford Encyclopedia of Philosophy,* Summer 2015, edited by Edward N. Zalta.

Graña, M. 2006. "The Low Energy Limit of String Theory and its Compactifications with Background Fluxes." *Letters in Mathematical Physics* 78 (3): 279–205.

Grünbaum, Adolf. 1968. *Geometry and Chronometry in Philosophical Perspective.* Minneapolis: University of Minnesota Press.

Haack, Susan. 1978. *Philosophy of Logics.* Cambridge University Press.

Hartz, Glenn A, and J.A. Cover. 1988. "Space and Time in the Leibnizian Metaphysic." *Noûs* 22:493–519.

Haslanger, Sally. 1989a. "Endurance and Temporary Intrinsics." *Analysis* 49 (3): 119–125.

———. 1989b. "Persistence, Change, and Explanation." *Philosophical Studies* 56 (1): 1–28.

Hawley, Katherine. 2001. *How Things Persist.* Oxford: Clarendon Press.

Hoefer, Carl. 1996. "The Metaphysics of Space-Time Substantivalism." *Journal of Philosophy* 93:5–27.

Hudson, Hud. 2006. "Confining Composition." *The Journal of Philosophy* 103 (12): 631–651.

Huggett, Nick, ed. 1999. *Space From Zeno to Einstein.* Cambridge, MA / London: The MIT Press.

Huggett, Nick, and Christian Wüthrich. 2013. "The emergence of spacetime in quantum gravity." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44 (3): 273–275. doi:`doi:10.1016/j.shpsb.2013.06.001`.

Inwagen, Peter van. 1981. "Why I Don't Understand Substitutional Quantification." *Philosophical Studies* 39 (3): 281–285.

Inwood, Michael. 1991. "Aristotle on the Reality of Time." In *Aristotle's Physics: A Collection of Essays,* edited by Lindsay Judson, 151–78. Oxford: Clarendon Press.

Jacobs, Jonathan. 2011. "Powerful Qualities, Not Pure Powers." *The Monist* 94 (1): 81–102.

Konyndyk, Kenneth. 1986. *Introductory Modal Logic.* Indiana: University of Notre Dame.

Kretzmann, Norman. 1982. "Syncategoremata, Exponibilia, Sophismata." In *Cambridge History of Later Medieval Philosophy,* edited by Norman Kretzmann, Anthony Kenny, and Jan Pinborg. Cambridge: Cambridge University Press.

Kung, Peter. 2010. "Imagining as a Guide to Possibility." *Philosophy and Phenomenological Research* 81 (3).

Le Poidevin, Robin. 1991. *Change, Cause, and Contradiction.* London: Macmillan.

Leibniz, G.W. 1989. *Philosophical Essays.* Edited by Roger Ariew and Daniel Garber. Hackett.

Lewis, David. 1973. *Counterfactuals.* Wiley-Blackwell.

———. 1976. "The Paradoxes of Time Travel" [in English]. *American Philosophical Quarterly* 13 (2): ISSN: 00030481. http://www.jstor.org/stable/20009616.

———. 1979. "Counterfactual Dependence and Time's Arrow." *Noûs* 13 (4): 455–476.

———. 1983. "New Work For A Theory Of Universals." *Australasian Journal of Philosophy* 61:343–377.

———. 1986. *On The Plurality Of Worlds.* Blackwell Publishing.

———. 1991. *Parts of Classes.* Oxford: Blackwell.

———. 1994. "Humean Supervenience Debugged." *Mind* 103 (412): 473–490.

———. 2004. "Tensed Quantifiers." In *Oxford Studies in Metaphysics,* edited by Dean Zimmerman, I:3–14. Oxford: Oxford University Press.

Lipman, Martin A. 2015. "On Fine's Fragmentalism." *Philosophical Studies.* doi:10.1007/s11098-015-0460-y.

Loemker, Leroy, ed. 1989. *Leibniz: Philosophical Letters and Papers.* Dordrecht: Kluwer Academic Publishers.

Loux, Michael J. 1997. "A Prolegomenon to a Substance Ontology." In *Contemporary Readings in the Foundations of Metaphysics,* edited by Cynthia Macdonald and Stephen Laurence, 233–247. Blackwell Publishing.

Lowe, E.J. 2005. "Vagueness and Endurance." *Analysis* 65:104–112.

Lycan, William G. 1979. "Semantic Compenetence and Funny Functors." *The Monist* 62 (2): 209–222.

Mach, Ernst. 1960. *The Science of Mechanics.* 6th ed. LaSalle, IL: Open Court Publishing Company.

Mariña, Jacqueline, and Franklin Mason. 2001. "Aristotle as A-Theorist: Overcoming the Myth of Passage." *Journal of the History of Philosophy* 39 (2): 169–192.

Markosian, Ned. 2004. "A Defense of Presentism." In *Oxford Studies in Metaphysics,* edited by Dean W Zimmerman, 1:47–82. Oxford: Oxford University Press.

———. 2014. "Time." In *The Stanford Encyclopedia of Philosophy,* Spring 2014, edited by Edward N. Zalta. http://plato.stanford.edu/archives/spr2014/entries/time/.

Mates, Benson. 1986. *The Philosophy of Leibniz.* New York: Oxford University Press.

Maudlin, Tim. 1990. "Substances and Space-Time: What Aristotle Would Have Said to Einstein." *Studies in History and Philosophy of Science Part A* 21 (4): 531–561.

———. 1993. "Buckets of Water and Waves of Space: Why Spacetime is Probably a Substance." *Philosophy of Science* 60 (2): 183–203.

McCall, Storrs, and E.J. Lowe. 2003. "3D/4D Equivalence, the Twins Paradox and Absolute Time." *Analysis* 63:114–123.

———. 2006. "The 3D/4D Controversy: A Storm in a Teacup." *Noûs* 40:570–578.

McGuire, James E. 1976. "'*Labyrinthus continui*': Leibniz on Substance, Activity, and Matter." In *Motion and Time, Space and Matter,* edited by Peter K. Machamer and Robert G. Turnbull, 290–326. Columbus: Ohio State University Press.

McTaggart, J. Ellis. 1908. "The Unreality of Time." *Mind* 17 (68): 457–474.

Melia, Joseph. 2005. "Truthmaking without truthmakers." In *Truthmakers: The Contemporary Debate,* edited by Helen Beebee and Julian Dodd. Oxford: Clarendon Press.

Mellor, D.H. 1981. *Real Time.* Cambridge: Cambridge University Press.

———. 1998. *Real Time II.* London: Routledge.

Meredith, C.A., and A.N. Prior. 1965. "Modal Logic with Functorial Variables and a Contingent Constant." *Notre Dame Journal of Formal Logic* 6 (2): 99–109.

Merricks, Trenton. 1999. "Persistence, Parts, and Presentism." *Noûs* 33:421–438.

Merricks, Trenton. 2007. *Truth and Ontology.* Oxford: Clarendon Press.

Meyer, Ulrich. 2013. *The Nature of Time.* Oxford University Press.

———. 2015. "Tense Logic." *Philosophy Compass* 10 (6): 406–419. doi:10.1111/phc3.12221.

Monton, Bradley. 2006. "Presentism and quantum gravity." *Philosophy and Foundations of Physics* 1:263–280.

———. 2011. "Prolegomena to Any Future Physics-Based Metaphysics." In *Oxford Studies in Philosophy of Religion,* edited by Jonathan L. Kvanvig, iii:142–165. Oxford University Press.

Mortensen, Chris. 2011. "Change and Inconsistency." In *The Stanford Encyclopedia of Philosophy,* Winter 2012, edited by Edward N. Zalta. http://plato.stanford.edu/archives/win2012/entries/change/.

Norton, John. 1987. "Einstein, the Hole Argument, and the Reality of Space." In *Measurement, Realism, and Objectivity,* edited by J. Forge, 153–188. Dordrecht: Reidel.

———. 1994. "The Hole Argument." *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* Two:56–64.

———. 2014. "The Hole Argument." In *The Stanford Encyclopedia of Philosophy,* Spring 2014, edited by Edward N. Zalta. http://plato.stanford.edu/archives/spr2014/entries/spacetime-holearg/.

Oaklander, L. Nathan. 2012. "A-, B-, and R-Theories of Time: A Debate." In *The Future of the Philosophy of Time,* edited by Adrian Bardon, 1–24. New York: Routledge.

Oriti, Daniele. 2014. "Disappearance and emergence of space and time in quantum gravity." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 46, Part B:186–199. doi:doi:10.1016/j.shpsb.2013.10.006.

Owen, G.E.L. 1976. "Aristotle on Time." In *Motion and Time, Space and Matter,* edited by Peter K. Machamer and Robert G. Turnbull, 3–27. Columbus: Ohio State University Press.

Padgett, Daniel, and T. Ryan Byerly. 2014. "Reconstituting Ersatzer Presentism." *Res Philosophica* 91, no. 3 (July): 491–502.

Palmer, John. 2009. *Parmenides and Presocratic Philosophy.* New York: Oxford University Press.

Perl, Caleb. 2015. “An argument for temporalism and contingentism.” *Philosophical Studies* 172:1387–1417. doi:10.1007/s11098-014-0355-3.

Plantinga, Alvin. 1974. *The Nature of Necessity.* Oxford University Press.

Poincaré, Henri. 2001. “The Measure of Time.” In *The Value of Science: The Essential Writings of Henri Poincaré,* 210–223. New York: The Modern Library.

Prior, A.N. 1968/2003. *Papers on Time and Tense.* Edited by P. Hasle, P. Ohrstrom, T. Braüner, and J. Copeland. Oxford: Oxford University Press.

———. 1970. “The Notion of the Present.” *Studium Generale* 23:245–248.

Prior, Arthur. 1967. *Past, Present, and Future.* Oxford University Press.

Prior, Arthur, and Kit Fine. 1977. *Worlds, Times, and Selves.* Amherst: University of Massachusetts Press.

Pruss, Alexander R. 2011. *Actuality, Possibility, and Worlds.* Continuum.

Quine, W.V.O. 1950. “Identity, Ostension, and Hypostasis.” *The Journal of Philosophy* 47:621–633.

Rasmussen, Joshua. 2015. “Tenseless Times.” *Philosophical Studies.* doi:10.1007/s11098-015-0466-5.

Rescher, Nicholas. 1979. *Leibniz: An Introduction to his Philosophy.* Totowa: Rowman / Littlefield.

Roberts, John T. 2003. “Leibniz of Force and Absolute Motion.” *Philosophy of Science* 70 (3): 553–573.

Rosen, Gideon. 2010. “Metaphyiscal Dependence: Grounding and Reduction.” In *Modality: Metaphysics, Logic, and Epistemology,* edited by Bob Hale and Aviv Hoffmann. Oxford: Oxford University Press.

Rovelli, Carlo. 2006. “The Disapperance of Space and Time.” In *The Ontology of Spacetime,* edited by Dennis Dieks, 1:25–36. Amsterdam: Elsevier.

Russell, Bertrand. 1936. “On Order In Time.” *Proceedings of the Cambridge Philosophical Society* 32:216–228.

Rynasiewicz, Robert. 2014. “Newton’s Views on Space, Time, and Motion.” In *The Stanford Encyclopedia of Philosophy,* Summer 2014, edited by Edward N. Zalta. http://plato.stanford.edu/archives/sum2014/entries/newton-stm/.

Scaltsas, Theodore. 1994. "Substantial Holism." In *Unity, Identity, and Explanation in Aristotle's Metaphysics,* edited by Mary Louise Gill Theodore Scaltsas David Charles, 107–128. Oxford: Clarendon Press.

Schaffer, Jonathan. 2009a. "On What Grounds What." In *Metametaphysics,* edited by Ryan Wasserman David Chalmers David Manley, 347–383. Oxford University Press.

———. 2009b. "Spacetime the One Substance." *Philosophical Studies* 145:131–48.

———. 2010a. "Monism: The Priority of the Whole." *Philosophical Review* 119:31–76.

———. 2010b. "The Internal Relatedness of All Things." *Mind* 119:341–376.

———. 2010c. "The Least Discerning and Most Promiscuous Truthmaker." *The Philosophical Quarterly* 60:307–324.

———. 2014a. "Monism." In *The Stanford Encyclopedia of Philosophy,* Winter 2014, edited by Edward N. Zalta. `http://plato.stanford.edu/archives/win2014/entries/monism`.

———. 2014b. "What Not To Multiply Without Necessity." *Australasian Journal of Philosophy (Forthcoming)* 93 (4): 644–664.

Schnieder, Benjamin. 2006. "Truth-making without Truth-makers." *Synthese* 152:21–46.

Seiberg, Nathan. 2006. "Emergent Spacetime." eprint: `hep-th/0601234`. `http://arxiv.org/abs/hep-th/0601234v1`.

Shoemaker, Sydney. 1969. "Time Without Change." *The Journal of Philosophy* 66:363–381.

Sidelle, Alan. 2007. "The Method of Verbal Dispute." *Philosophical Topics* 35 (1/2): 83–113.

Sider, Theodore. 2001. *Four-Dimensionalism.* Oxford: Clarendon.

———. 2005. "Traveling in A- and B-Time." *The Monist* 88:329–335.

———. 2011. *Writing The Book of The World.* Oxford University Press.

———. 2013. "Against Parthood." In *Oxford Studies in Metaphysics,* edited by Karen Bennett and Dean W Zimmerman, 8:273–293. Oxford: Oxford University Press.

Sklar, Lawrence. 1974. *Space, Time, and Spacetime.* University of California Press.

Skow, Bradford. 2010. "Extrinsic Temporal Metrics." In *Oxford Studies in Metaphysics,* edited by Dean Zimmerman, 5:179–202. Oxford: Oxford University Press.

Sleigh Jr, Robert C. 1990. *Leibniz and Arnauld: A Commentary on Their Correspondence.* New Haven: Yale University Press.

Smart, J.J.C. 1963. *Philosophy and Scientific Realism.* London: Routledge / Kegan Paul.

Strawson, Peter. 1959. *Individuals.* London: Methuen.

Sullivan, Meghan. 2012. "The Minimal A-Theory." *Philosophical Studies* 158:149–174.

———. 2014. "Change We Can Believe In (and Assert)." *Noûs* 48 (3): 474–495. doi:`10.1111/j.1468-0068.2012.00874.x`.

Šuráň, Josef. 1997. "A Calendar for Mars." *Planetary and Space Science* 45 (6): 705–708.

Swinburne, Richard. 2004. *The Existence of God.* 2nd. Oxford University Press.

———. 2010. *Is There a God?* New York: Oxford University Press.

Tallant, Jonathan. 2008. "What Is It To "B" a Relation?" *Synthese* 162 (1): 117–132.

———. 2015. "Ontological Dependence in a Spacetime-World." *Philosophical Studies* 172 (11): 3101–3118. doi:`10.1007/s11098-015-0459-4`.

Textor, Mark. 2014. "States of Affairs." In *The Stanford Encyclopedia of Philosophy,* Summer 2014, edited by Edward N. Zalta. `http://plato.stanford.edu/archives/sum2014/entries/states-of-affairs/`.

Thiemann, Thomas. 2008. *Modern Canonical Quantum General Relativity.* Cambridge: Cambridge University Press.

Thomason, Richmond H. 1984. "Combinations of Tense and Modality." In *Handbook of Philosophical Logic,* edited by F. Guenthner D. Gabbay, II:135–165. Dordrecht: D. Reidel Publishing Company.

Todd, Patrick. (forthcoming). "On Behalf of a Mutable Future." *Synthese:* 1–19.

Tomaszewski, Christopher M. P. 2016. "The Principle of Sufficient Reason Defended: There Is No Conjunction of All Contingently True Propositions." *Philosophia:* 1–8. doi:10.1007/s11406-016-9686-y.

Tooley, Michael. 1997. *Time, Tense, and Causation.* Oxford: Clarendon Press.

Trogdon, Kelly. 2013. "An Introduction to Grounding." In *Varieties of Dependence,* edited by Miguel Hoeltje, Benjamin Schnieder, and Alex Steinberg. Munich: Philosophia Verlag.

Van Benthem, Jeremy. 1983. *The Logic of Time.* Dordrecht, Boston / London: Kluwer Academic Publishers.

Van Cleve, James. 2011a. "Rates of Passage." *Analytic Philosophy* 52, no. 3 (September): 141–170.

———. 2011b. "Reid on the Real Foundation of the Primary-Secondary Quality Distinction." In *Primary and Secondary Qualities,* edited by Lawrence Nolan. Oxford: Oxford University Press.

Van Fraassen, Bas. 1970. *An Introduction to the Philosophy of Time and Space.* New York: Random House.

Varzi, Achille. 2015. "Mereology." In *The Stanford Encyclopedia of Philosophy,* Winter 2015, edited by Edward N. Zalta.

Von Leyden, W. 1964. "Time, Number, and Eternity in Plato and Aristotle." *The Philosophical Quarterly* 14 (54): 35–52.

Wallden, P. 2010. "Causal Sets: Quantum gravity from a fundamentally discrete spacetime." *Journal of Physics: Conference Series* 222: 012053.

Wasserman, Ryan. 2016. "Theories of Persistence." *Philosophical Studies* 173 (1): 243–250. doi:10.1007/s11098-015-0488-z.

Whitehead, Alfred North. 1919. "Time, Space, and Material." *Aristotelian Society Supplement* 2:44–57.

Wildman, Nathan. 2015. "Load Bare-ing Particulars." *Philosophical Studies* 172 (6): 1419–1434. doi:10.1007/s11098-014-0356-2.

Williams, D.C. 1951. "The Myth of Passage." *Journal of Philosophy* 48:457–472.

Wilsch, Tobias. 2015. "The Nomological Account of Ground." *Philosophical Studies.* doi:10.1007/s11098-015-0470-9.

Winterbourne, A.T. 1982. "On the Metaphysics of Leibnizian Space and Time." *Studies in History and Philosophy of Science* 13:201–214.

Wüthrich, Christian. 2010. "No Presentism In Quantum Gravity." In *Space, Time, and Spacetime: Physical and Philosophical Implications of Minkowski's Unification of Space and Time,* edited by V. Petkov, 257–278. Berlin: Springer.

Zalta, Edward N. 1987. "On The Structural Similarities Between Worlds and Times." *Philosophical Studies* 51 (2): 213–239.

Zimmerman, Dean W. 1998. "Temporary Intrinsics and Presentism." In *Metaphysics: The Big Questions,* edited by Peter van Inwagen and Dean W Zimmerman, 206–218. Oxford: Blackwell.

———. 2005. "The A-Theory of Time, The B-Theory of Time, and 'Taking Tense Seriously'." *dialectica* 59 (4): 401–457.

———. 2011. "Presentism and the Space-Time Manifold." In *The Oxford Handbook of Philosophy of Time,* edited by Craig Callender. Oxford: Oxford University Press. doi:`10.1093/oxfordhb/9780199298204.003.0008`.