

**METAPHYSICS AND NATURAL KINDS: SLINGSHOTS,
FUNDAMENTALITY, AND CAUSAL STRUCTURE**

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DISSERTATION ABSTRACT

Metaphysics and Natural Kinds: Slingshots, Fundamentality, and Causal Structure

Andrew Lee McFarland

My dissertation addresses a question relevant to metaphysics, philosophy of language, and philosophy of science: What are natural kinds? I explore a view that holds that natural kinds are complex, structural properties that involve *causal structure*. Causal structure describes the idea that for the many properties associated with natural kinds, these properties are *nominally* linked – that is causally connected – in such a way that the properties of non-natural kinds are not. After criticizing arguments in favor of a nominalist theory of kinds – one that holds that a natural kind just is to be identified with its class of instances – and after defending the notion of a complex structural property from several prominent objections posed by David Lewis, I apply a causal account of natural kinds to a set of problematic cases, paying special attention to isomeric kinds from chemistry.

Dedication

I dedicate this doctoral thesis to my family and to the tireless support they have given me over the years.

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1. DISSERTATION PROSPECTUS

1.1 INTRODUCTION & MOTIVATIONS

The topics addressed in the foregoing essays have their origins in lingering questions from post-Kripkean and post-Putnamian concerns about the semantics of natural kind terms: If natural kind terms are non-descriptive and directly referential, what are natural kinds? The view I explore in this series of essays holds that natural kinds are complex, causally structured properties. By “complex”, I mean that they are in some way “built up” from other simpler properties. By “causally structured”, I mean that they involve certain causal or nomological connections that other kinds do not. Although the origin of this thesis arose out of questions about the semantics of a limited class of general terms, the ultimate question and the candidate answer to it explored here, is a metaphysical one. I will begin by briefly setting out some of the linguistic motivations for asking this question. Next I will sketch the lay of the land by discussing some candidate views one might adopt to answer the question, and then I will describe the structure of the dissertation.

1.1.1 THE DESCRIPTONALIST THEORY

The Descriptonalist theory begins with the semantic theories of Gottlob Frege and Bertrand Russell, and their theories concerning certain sorts of expressions, namely referring or in Russell’s terminology “denoting” expressions. Referring expressions include definite descriptions like “The 44th President of the United States” or “Obama’s eldest daughter”; proper names like “Socrates”, “North America”, and “Earth”; indexicals, “I”, “me”, “now”; demonstrative expressions, “that ferocious dog over there” or “this delicious piece of pie”, and so on. Referring expressions that refer to or denote a single thing, namely the *referent* of the term, are called *singular terms*. The referent of a definite description like “The 44th President of the

United States” is the man, Barack Obama, and naturally, that same individual is the referent of the proper name “Barack Obama”.

According to the Descriptivist theory, singular terms have in addition to a referent, a *sense*, that is a manner or way the object denoted by the term is presented to the hearer or reader. The sense of an expression was thought to play three different theoretical roles: as a conceptual or psychological depiction of an object that a competent speaker associates with that object; as the linguistic “device” that functions to secure or pick out the referent of the term; and as something providing the semantic content or meaning of that term. The Descriptivist theory can be roughly characterized as the view that, for a certain class of referring expressions, the sense of those expressions plays all three of these theoretical roles.² In a similar manner, the Descriptivist project concerning general, but more specifically for our purposes here natural kind terms, asserts several analogous theses: that natural kind terms are referring expressions, and hence have referents; that there is in addition to the referent of a natural kind term, a sense that plays the three theoretical roles played by the senses of singular terms; and a sense for a natural kind term like “water” can be given descriptively, as in “the transparent liquid that fills lakes and streams, that is required for sustaining life, quenches thirst, boils at 100°C and freezes at 0°C...”. Thus, according to a Descriptivist theory, natural kind terms and singular terms are analogous, but with one notable point of difference. Singular terms apply to a single individual, while general terms can apply to more than one individual.

1.1.2 REJECTING THE DESCRIPTIVIST THEORY OF NATURAL KIND TERMS

If the Descriptivist theory is right, then the sense of a natural kind term like “water” plays several theoretical roles. The sense of water functions as a conceptual or psychological

² See Burge (1977) for this tripartite distinction. Cf. Salmon (2005).

depiction of the kind in the mind of competent users of a language; it acts as the linguistic device that secures the referent of that term; and it gives the semantic content or meaning of the term as well. The rejection of the Descriptivist thesis, both for singular terms and natural kind terms, comes from a number of compelling arguments against a sense's capacity to fulfill each of these three theoretical roles.

Two of the most notable figures offering anti-Descriptivist arguments are Hilary Putnam (1975) and Saul Kripke (1980). In Putnam's now famous *Twin Earth* thought experiment, he asks us to imagine a world called "Twin Earth". Twin Earth is qualitatively identical with our own planet Earth, except that the colorless liquid filling the lakes and streams of Twin Earth does not have the chemical composition H_2O , but has instead another complex chemical constitution that Putnam abbreviates "XYZ". Despite the fact that the substance on Twin Earth is qualitatively indistinguishable from the substance we call "water" here on Earth, and despite the fact that residents of Twin Earth also use the term "water" when referring to the substance of their planet, the intuitive pull of Putnam's experiment is the denial of key components of the Descriptivist thesis. If the Descriptivist thesis were correct, then one would expect both the psychological content of competent language users and the semantic content of expressions containing the relevant terms for Twin Earth and Earth to be the same. However, "Water" when uttered on Twin Earth refers to the substance with chemical composition XYZ, while "water" when uttered on Earth refers to the substance composed of H_2O . Likewise, the mental content of Twin Earthlings in the presence of XYZ is intuitively XYZ, rather than H_2O , contrary to the Descriptivist thesis. Putnam takes this to show that the meanings and referents of natural kind terms are determined by certain factors external to us, or as he puts it, that meanings "just ain't in the head".

In Kripke's *Naming and Necessity* we're given several anti-Descriptivist arguments for both proper names and natural kind terms, which can be classified as the *modal*, the *epistemological*, and the *semantic* arguments.³ Salmon (2005) describes the structure of all three arguments as follows:

We consider a particular term τ of the sort in question [natural kind expressions]. If τ were descriptive in terms of the properties which one might associate with τ as forming its sense, then certain systematic metaphysical, epistemological, and semantical consequences would have to obtain. Intuitively these consequences do not obtain; therefore τ is not descriptive in terms of these properties (61).

For example, if the Descriptivist theory is right about the natural kind term "water", then the sentence, "water is the transparent liquid that fills lakes and streams, that is necessary for sustaining life, quenches thirst, boils at 100°C and freezes at 0°C", would be a necessary truth. Further, according to the Descriptivist theory, the sentence would be an analytic truth since the meaning of the term is identified with the associated description. Finally, the proposition expressed by the sentence should also be one that is knowable *a priori*. But intuitively, it's surely the case that water might have been opaque or that some other substance might have filled our lakes and streams. However, if this is right, then imagining a world in which water is opaque and does not fill our lakes and streams should be as incoherent as a married bachelor. What's more, that water displays these characteristics seems to be a genuine empirical discovery, and thus knowable *a posteriori*, contrary to the Descriptivist theory.

If the Putnam and Kripke arguments are on the right track, that the Descriptivist theory of proper names and natural kind terms is incorrect, what then is the meaning of a proper name or a general term? For the class of proper names, *Millians* (named in honor of J.S. Mill)

³ See Salmon (2005) for a very thorough overview of the descriptivist project, and the arguments mustered against it from the Millian camp.

hold that the contribution a proper name makes to the propositions expressed by sentences in which they occur, just is the *referent* of the name. In other words, the meaning of a proper name like “Aristotle” just is the referent of that term, namely the man Aristotle. If we then apply analogous reasoning to natural kind terms, it follows that the semantic contribution a natural kind term makes to the propositions expressed by sentences in which they occur is just the referent of the term itself. In other words, the meanings of natural kind terms like ‘water’, ‘gold’, or ‘tiger’ just are those very kinds themselves; those kinds are the semantic contribution made to sentences in which those terms occur. But now it seems that we are led almost unavoidably to ask a deeper metaphysical question: What are natural kinds?

Before getting into the detailed philosophical argumentation for answering this metaphysical question, we can begin with a very simple first approximation and say that natural kinds are natural categories or classifications into which we group or classify things. We might also say that typical examples of natural kinds come from theoretical categories given to us by the natural sciences, which include things like the chemical elements – hydrogen, gold, and plutonium – biological taxa – species like tiger, *Panthera tigris*, porcini mushroom, *Boletus edulis*, and the main bacterial species responsible for food poisoning, *Salmonella enterica* – forms of precipitation – snow, rain, and hail, and perhaps even those categories employed in the social sciences. However, going beyond this initial characterization becomes much more difficult. So how should we proceed in answering the metaphysical question?

Since the question we are entertaining is a metaphysical one, we can frame our answers to that question in metaphysical terms as well. Typical metaphysical entities include properties – the property of *being red*, *being boisterous*, or *being negatively charged* – relations – *being exactly 5 meters from*, *loving*, or *being a sibling of* – and individuals like Barack Obama, the

planet Mars, or the *Mona Lisa*. We can think of the guiding question about natural kinds then as whether they are to be construed in terms of properties, relations, and individuals, or whether kinds are a *sui generis* entity, which itself is distinct from and not to be countenanced in terms of these other fundamental entities. As I have already stated, this dissertation will explore the view that kinds can be construed in such a way as to avoid positing another fundamental *sui generis* entity of *kind*. As I go on to argue, this theory has the potential to handle some very difficult cases.

1.2 ORGANIZATION

Before discussing kinds as complex, structural properties, we should consider an extremely parsimonious view about natural kinds. Suppose we put forth the thesis that we don't even need properties and relations to answer the question of what natural kinds are. Suppose instead that we approach this issue in a way that construes kinds without properties at all, as simply classes of individuals. According to this approach kinds are like sets in that they are to be identified with and determined by their members. Natural kinds according to this approach are simply classes of individuals. Thus, this view is minimalist in the sense that it doesn't require natural kinds to be anything beyond just a class of members. The theory gives an account of kinds without having to appeal to properties. Let's call this the *Extensional View*.

To be more precise, let's adopt some somewhat technical terminology. Following Nathan Salmon (2005), let's say that the *metaphysical extension* of a kind *k* at a possible world *w* (at a time *t*) is the class of instances of *k* at *w* (at *t*). By this characterization the metaphysical extension of a kind *k* will be identical with the *semantic extension* of the natural kind term of the kind *k*. In this respect, the metaphysical extension of a kind is the metaphysical *analogue* to the linguistic notion of semantic extension. According to the Extensionalist View, a kind *k* will be

identified with its metaphysical extension and the identity conditions for being of the same kind will consist of having the same metaphysical extension. For example, the kind *molecule of water* and the kind *molecule composed of H₂O* have the same metaphysical extension because they have the same class of instances at this the actual world. Thus, according to the Extensional View, the natural kind *water* and the natural kind *H₂O* are identical. Quine (1977) briefly discusses a view similar to what I'm here calling the Extensional View, saying, "Kinds can be seen as sets, determined by their members. It is just that not all sets are kinds" (158). This discussion of individuation by members, however, is short-lived, as Quine is concerned primarily with investigating first, the relationship between *similarity* and *kind*, both notions he claims are inter-definable, and second the relationship between kinds and inductive reasoning in the natural sciences. He ultimately concludes that notions like *kind* will give way in the wake of scientific inquiry, and will eventually be replaced with scientific predicates.

However, it may be thought that the Extensional View goes awry. Consider the kinds *creature with a heart* and *creature with kidneys* or the kinds *Tyrannosaurus rex* and *dodo*. These pairs of kinds are metaphysically coextensional – every creature with a heart is also a creature with kidneys and vice versa and T-rexes and dodos are extinct – which on the extensional view means the kinds are the same. But this is an implausible view, so perhaps we should abandon this view of kinds, even though it's more ontologically parsimonious than a theory requiring properties and relations.

Suppose however that the advocate of the Extensionalist View replies that the above reasoning is flawed, and that moreover, there is a semi-formal argument to be had which shows that natural kind terms just refer to classes of entities. This semi-formal argument has come to be known as the Slingshot, and one can very easily modify it for the class of natural kind terms.

If right, the Slingshot would *prove* that natural kind terms just refer to predicate extensions, and this gives us good evidence to think the Extensionalist View is right. In Essay 1, I discuss the famous Slingshot argument and what, if any, metaphysical consequences one may draw from it.

Suppose instead that one is convinced that the Extensionalist View is flawed. Following Salmon again, let's say that the *metaphysical intension* of a kind k is the function that assigns to any possible world w (at a time t) the metaphysical extension of k at w (at t). The Intensional View holds that sameness of metaphysical intension is sufficient for sameness of kind. In other words, this view holds that whenever "two" kinds share exactly the same instances across all possible worlds, then those kinds are really one and the same kind. This view accords with the claim that kinds are individuated by their possible instances. To illustrate, for every possible world w (at a time t), every instance of the kind *molecule of water* is also an instance of the kind *molecule composed of H_2O* (and vice versa). So on the Intensional View, the kind *molecule of water* and *molecule composed of H_2O* are the same, since they share the same metaphysical intension.

Admittedly, the Intensional View appears to have intuition on its side. For example, Scott Soames (2007) says "It is hard to imagine two distinct species of animal, two distinct substances, or two distinct colors which have precisely the same instances in every possible world-state". Even if the view seems intuitive to some, it requires a fuller, more detailed description of what the view amounts to and it requires a stronger defense other than one which appeals only to intuition for its support. Suppose then contrary to the Extensionalist picture described earlier, we construct a view of natural kinds appealing to properties and relations, and we specify a way that more basic fundamental properties can be built-up in such a way to generate other, more complex properties. The general idea is to provide of list of the most basic

ontological entities - those things which are the most “simple” so to speak - and then try and specify how we can get other sorts of more complex entities from this basic stock. Being able to formulate a view like this would have several upshots. If successful, it would legitimize talk of kinds, while still aiming to remain ontologically parsimonious. It would give us a fuller picture for how kinds are to be individuated, which the very general modal criterion provided for with the Intensional View said very little about. And finally, if the causal approach to natural kinds I explore here is correct, it would offer a potentially nice way to account for some topics discussed in the philosophy of science like the projectibility of natural kind terms.

It is providing this framework for the complexity and structure of properties that is explored in Essays 2 and 3. Essay 2 gives a defense of an account of structural properties from David Armstrong against prominent objections raised by David Lewis. Essay 3 develops the claims about structure and causation by looking carefully at cases of chemical isomeric kinds in chemistry by appealing to Shoemaker’s (1980) causal theory of properties.

1.3 SUMMARIES OF THE ESSAYS

1.3.1 - 1: WHAT CAN YOU DO WITH A SLINGSHOT?

Most philosophers today will acknowledge the pitfalls of confusing metaphysical and semantic issues.⁴ Many are also familiar with the classic semi-formal argument that has come to be known as ‘the Slingshot’ and the various philosophical ends to which this argument has been deployed. With this in mind, one might ask the following question: Is it possible to construct a sound Slingshot-style argument for natural kind terms? Such a conclusion would strongly support a nominalist theory of natural kinds, where natural kinds just are their instances. However, against this argument it is important to remember several things. The slingshot was

⁴ Devitt (1991) for instance, in his defense of realism, distinguishes between metaphysical questions and semantic questions.

originally conceived as a semantic argument about designation; what it suggests, but does not prove, is that the closest analogue to singular term reference for any expression is that expression's semantic extension. In order to derive more metaphysically robust conclusions, however, the classical deployments of the argument, as well as the natural kind term version of it, make use of several methodologically suspect tactics. By cataloguing the more frequent abuses of the argument, we may remind ourselves of a valuable philosophical lesson: to be cautious when attempting to derive metaphysical conclusions from semantics.

1.3.2 - 2: ON BEHALF OF STRUCTURAL UNIVERSALS

David Lewis famously argued against structural universals. This essay observes that those objections of Lewis's that appear the most powerful, namely those whose charge is that of incoherence, depend on an important but unmentioned premise. This premise presupposes a particular picture of Lewis's own view of fundamentality, a thesis that forms a cornerstone to his famed thesis of *Humean Supervenience*. Given that Armstrong's own ontology is one involving *states of affairs* rather than a Lewisian *Humean mosaic*, those objections of Lewis's initially appearing the most devastating instead now appear to beg the question. Although states of affairs are incompatible with Humean Supervenience as Lewis conceived of it, I argue that the incompatibility is with only one part of that thesis, and so there is room for Armstrong to modify the thesis without abandoning it in its entirety.

1.3.3 - 3: CAUSAL STRUCTURE AND THE ISOMER PROBLEM

Chemical kinds are often regarded as paradigmatic cases of natural kinds. The natural kind *water*, for instance, is characterized by its chemical formula 'H₂O'; atoms of the element *gold* are characterized by their having the atomic number 79. This has led some to adopt a view that natural kinds, in particular chemical kinds, can be characterized in a purely *constitutive* way.

That is, natural kinds are individuated solely in terms of the constituents that make them up. This essay argues that some constitutive approaches which hold that the constituents of complex chemical properties can “read off” from their molecular formulae, are in fact too simple. This “simple constitutive approach” fails to take into account that there are facts about the causal relations obtaining between properties associated with chemical kinds in virtue of which they are individuated. The causal structure of a kind is both tied to a kind’s causal profile, that is, the powers that members of a kind possess, and also constitutive of the kind as well. To show the inadequacy of the simple constitutive account, I focus on the case of chemical isomers. I then elaborate on the notion of causal structure for natural kinds by appealing to Sydney Shoemaker’s causal theory of properties.

1.4 SIGNIFICANCE & OUTCOMES

Historically there has been disagreement between those philosophers interested in metaphysics, and those who have fallen on the more empirical and scientifically minded side of debates. The apex of this controversy was perhaps embodied most forcefully in the logical positivist call for the elimination of metaphysics. Recently however there has been renewed interest in classical metaphysical notions from those in the more empirically minded camp. Topics like causation, individuality, and natural kinds, just to name a few, have received much attention from metaphysicians and philosophers of science alike (Bird 2007, Cartwright 2002, Khalidi 2013, Maudlin 2007, Mumford & Tugby 2013, Mumford and Anjum 2011, Woodward 2003, etc.). This new interest in the metaphysics of science stems from the desire to understand certain metaphysical notions and the roles those notions play within the natural sciences (Ladyman & Ross, et al. 2009).

With respect to natural kinds, there has also been an interest from philosophers of science in the role that causation plays in how we explain what natural kinds are. For example, the *homeostatic property cluster* concept as sketched by Boyd (1999a, 1999b) is one such example. More recently, Khalidi (2013) defends a view of kinds he thinks

...is a naturalist position, which takes into account the discoveries of various scientific disciplines while at the same time trying to derive general conclusions about the validity of our categoris. The pigeonholes into which we slot objects in the world are convenient devices that enable us to fulfill our explanatory needs and predict future contingencies, but insofar as they succeed in this regard, they do so precisely *because they are attuned to regularities and patterns in the natural world* (x).

Later, Khalidi remarks more on what he means by these regularizes:

On this theory, natural kinds are associated with a set of properties that are *causally linked to other properties*...When the properties associated with a natural kind are instantiated or co-instantiated, they lead reliably to the instantiation of a number of other properties. Since they are implicated in repeatable patterns of properties, they enable us to explain and predict phenomena in the natural and social worlds (201).⁵

The causal patterns, or as Khalidi himself says later, “causal structure” (208) of these properties is what underwrites our predictive abilities.

While those philosophers of science like Boyd and Khalidi discuss the topic of natural kinds from a primarily epistemological approach, the desire to have a theory of natural kinds that still in some way latches onto something real in the world comes through, at least every once in a while. If the causal approach to natural kinds I discuss here is right, then the view provides a metaphysical account employing traditional metaphysical notions that even contemporary philosophers of science are themselves invoking. Thus, the account takes seriously the results

⁵ Emphasis added in both quotations.

from the natural sciences, along with considerations from the philosophy of language, and of course metaphysics itself.

The first essay below deals mainly with the semantic question of *reference* – that is what do different designating expressions *refer to* or *designate*? In particular, what do natural kind terms refer to? Although the topic is semantic one, the main methodological lesson I go on to draw is informative for metaphysics in that it urges caution when trying to derive substantive metaphysical conclusions from semantics. Making this methodological point serves a couple purposes. First, it helps to focus the question to be addressed as one of metaphysics rather than an investigation about the meanings of natural kind terms or an investigation about natural kinds as merely epistemological categories. Second, and more broadly, in drawing attention to the methodologically suspect ways that classical deployments of the Slingshot argument have been incorrectly used, we will be far less inclined to accept arguments employing similar suspect strategies in the future.

Essay 1

2. WHAT CAN YOU DO WITH A SLINGSHOT?⁶

2.1 INTRODUCTION

There is a familiar argument whose formal presentation is due originally to Alonzo Church (1943, 1956) and independently to Kurt Gödel (1944) that has been used for a number of philosophical purposes. In its first form, in his review of Carnap's *Introduction to Semantics* (1942), Church presented the argument as a rigorous proof against the view that sentences refer to propositions. Others like Davidson (2001a, 2001b, 2001c) and Quine (1960, 1961, 1975) have employed similar arguments in attempts to undermine various philosophical theses. If successful these arguments would have profoundly startling results: (i) all true sentences corefer (and so too with all false sentences); (ii) if sentences refer to facts, then there is but one "Eleatic" fact; and (iii) anyone who has a true belief, believes everything that is true (and similarly anyone who believes anything false, believes everything false) or finally (iv) that all true sentences are necessarily true. Unsurprisingly, this argument has gone by several different names: the Frege-Church-Gödel argument – as the formal argument appears to have its roots in the work of Frege – collapsing arguments, and perhaps most famously the Slingshot.

The most comprehensive work to date on slingshot arguments is Stephen Neale's *Facing Facts* (2001), which discusses some of the more prominent versions of slingshots as well as their philosophical significance, paying special attention to a version Gödel (1944) outlines in discussion of Russell's theory of descriptions. Ultimately, Neale concludes with Gödel that in order to avoid the argument's intended conclusion of a metaphysical "collapse" of all facts into

⁶ This chapter draws from an essay which appeared in December of 2013 entitled, "Misfired Slingshots: A Case Study in the Confusion of Metaphysics and Semantics", *Logos & Episteme*, IV, 4, (2013): 407-432.

one, one must “give up either (i) an intuitive and straightforward Fregean Principle of Composition or (ii) the idea that definite descriptions are expressions that purport to stand for things” (128). Since giving up compositionality would appear too high a price to pay, one can give up the view that definite descriptions refer. In other words, if one adopts a Russellian treatment of definite descriptions, a theory for which there is, as Neale claims, independent motivation to accept, then one has the means to avoid Eleatic metaphysical collapse.⁷

Although much ink has been spilled in discussing various slingshot deployments, there is surprisingly widespread abuse of this now classic argument. The Slingshot was so-dubbed by Barwise and Perry (1981) due to its relatively simple philosophical machinery, and its apparent giant-slaying abilities. What’s more, the argument is as close to a formally rigorous philosophical argument as you will find. The combination of its simplicity and its formal character make the slingshot ripe for abuse. Under proper scrutiny, such abuse reveals several highly methodologically dubious strategies, which I will detail below, that significantly weaken the arguments.

My plan will be as follows. In Section 2.2, in order to understand the original Fregean-inspired motivations behind the slingshot, it will be useful to examine it in its earliest forms; doing this will require going back to Frege, since Church, Gödel, Quine and Davidson, like so

⁷ Recall that Russell gives definite descriptions of the form, ‘the ϕ ’, a quantificational analysis. Thus a Russellian analysis of “the author of *The Brothers Karamozov*” will have the following structure:

$$\exists x \forall y [Kx \ \& \ (Ky \rightarrow x=y)]$$

This can be read as saying that there is one and only one individual who authored *The Brothers Karamozov*, where ‘K’ stands for the predicate ‘is author of *The Brothers Karamozov*’. The reason why Gödel thought the slingshot’s conclusion could be avoided with a Russellian theory is that this quantificational analysis doesn’t treat descriptions as genuinely referring expressions. And since the slingshot relies on the assumption that one may substitute constituent coreferring singular terms *salva designante*, such a substitution will count as illegitimate by Russell’s lights.

many were inspired by his pioneering work. Those already familiar with the historical beginnings of the argument may skip ahead to later sections. In Section 2.3 I shall examine several contemporary slingshots, one proposed by Quine (1961), one by Donald Davidson (2001b, 2001c), and a more recent one discussed by Nathan Salmon (2005). Section 2.4 is devoted to a brief discussion of various principles of substitution. Finally, in Section 2.5, I will catalogue a number of mistakes commonly employed in slingshot-style argumentation with an aim to learning a larger philosophical lesson: to use caution when drawing metaphysical conclusions from linguistic arguments.

2.2 HISTORICAL BACKGROUND: FREGE, CHURCH, AND GÖDEL⁸

2.2.1 *SINN AND BEDEUTUNG* AND FREGE'S "SLINGSHOT"

The extent to which there is anything one can call a formalized slingshot in the work of Frege is somewhat controversial.⁹ Regardless of whether we can correctly attribute to Frege a slingshot argument, it will be worthwhile – especially since both Church and Gödel took themselves to be articulating Frege's implicit reasoning – if we examine his motivations.

The distinction between *sense* and *reference* makes its first appearance in "Function and Concept" (1891), and was later developed in more detail in "On Sense and Reference" (1892). In the former, the distinction gets invoked in connection with discussions of mathematical statements concerning the identity sign, " $=$ ". At the time, there was debate about how to interpret the identity symbol for an expression like " $2 + 5 = 3 + 4$ ", where some favored the view

⁸ I shall use the terms "referent" and "designation", along with their plural versions, interchangeably throughout.

⁹ As one (re)reads *On Sense and Reference*, one does get a feeling of sorts that a slingshot-style argument is precisely what Frege had in mind, although the question of whether there is an actual slingshot argument in that essay is a question for Frege scholarship. Answering this question definitively will have no effect on the outcome of the current essay.

that this sentence expresses an *equality*, but not a strict *identity*. Frege explicitly disagrees with this assessment, claiming that the expressions flanking the identity sign both designate one and the same thing, the number seven, though the thing signified is presented, or picked out differently by the two expressions.¹⁰ Those favoring the equality interpretation of the identity sign confuse the “sign and thing signified” (22). It is as if “one wanted to regard the sweet-smelling violet as different from *Viola odorata* because the names sound different. Difference of sign cannot by itself be a sufficient ground for difference of the thing signified” (22). Thus Frege makes a distinction between the number being picked out – in this example the number seven – and the way that that thing is determined by an expression like “2 + 5”. The former Frege calls the *reference* (*Bedeutung*). The latter, the “mode of presentation”, he calls the *sense* (*Sinn*).

Later, in “On Sense and Reference”, the theory of Sense and Reference was expanded to include all linguistic expressions. By including both non-natural and natural languages as admitting of this distinction, Frege was able to give a solution to his now eponymous puzzle. Consider the pairs of sentences

- (1) Hesperus = Hesperus
- (2) Hesperus = Phosphorus

It seems we’re left with the following question: given that the names “Hesperus” and “Phosphorus” corefer – i.e. they refer to the very same object, the planet Venus – how can a sentence like (1) with the form ‘ $a = a$ ’ differ in cognitive value from a sentence like (2) with the form ‘ $a = b$ ’, since the former is uninformative, trivial, and knowable *a priori* while the latter is presumably potentially informative, non-trivial, and knowable *a posteriori*? By invoking the two different semantic values of sense and reference, Frege has a means to answer this puzzle. While

¹⁰ See Klement (2002) for a nice overview of this debate.

the names in both (1) and (2) refer to the same thing, the planet Venus, those names have different senses. Thus, according to Frege ‘Hesperus’ and ‘Phosphorus’ have different senses, which explains the difference in semantic content, though they both *refer* to one and the same object.

The two examples just discussed raise the puzzle by use of *singular terms*, i.e. terms purporting to pick out singular, unique entities.¹¹ However, in positing two distinct semantic values for the class of singular terms, it would appear quite natural to extend this distinction to other expressions as well. For example, does the sense/reference distinction hold for larger expressions, say, for entire declarative sentences? In response, Frege says that a whole sentence may be regarded as a name and that each sentence contains what Frege calls “a thought [Gedanke]” (62). Tabling the question of what exactly Fregean thoughts are for a moment, one might then pose the question of whether a thought is the sense or the reference of a sentence. Here, it is worth quoting Frege in full:

Let us assume for the time being that the sentence has reference. If we now replace one word of the sentence by another having the same reference, but a different sense, this can have no bearing upon the reference of the sentence. Yet we can see that in such a case the thought changes; since, e.g., the thought in the sentence ‘The morning star is a body illuminated by the Sun’ differs from that in the sentence ‘The evening star is a body illuminated by the Sun.’ Anybody who did not know that the evening star is the morning star might hold the one thought to be true, the other false. The thought, accordingly, cannot be the reference of the sentence, but must rather be considered as the sense (62).

This passage is important for several reasons: first, we’re given a couple of crucial assumptions for Frege’s argument about the referents of sentences. Second and more importantly, these two

¹¹ It is important to note that Frege included in the class of singular terms proper names, like ‘Hesperus’ or ‘Aristotle’, mathematical expressions like ‘ $2 + 2$ ’, and unlike Russell, definite descriptions such as ‘the founder of the Lyceum’.

assumptions are also invoked in Church's slingshot appearing in 1943. Third, using these assumptions, Frege argues for the conclusion that the thought of a sentence cannot be its referent, but must be the sense. Let's name the two assumptions just mentioned as follows:

SR: Sentences are referring expressions

SUB_{DES}: The referent of a compound referring expression - not containing devices like quotation marks or "believes that" - is preserved when a component referring expression is replaced by another with the same referent.

The first assumption merely reflects Frege's tentative proposal to accept that sentences have references, while the second assumption reflects important rules of substitution for singular terms. *SUB_{DES}* is therefore a generalized principle of substitution for compound expressions, an analogue to similar principles regarding the substitution of coreferring singular terms. The qualification in *SUB_{DES}* is important both from a logical perspective and an historical one, for even Frege is careful to remark on the importance of the principle's restricted application for nonextensional contexts: "Exceptions are to be expected when the whole sentence or its part is direct or indirect quotation; for in such cases, as we have seen, the words do not have their customary reference" (65). One other notable remark about Frege's motivations (and so too with Church) is that Frege sought a *theoretical analogue* to singular term reference for the class of larger expressions. Calling this an analogue is appropriate, for it seems even Frege himself recognized the counterintuitive nature of positing sentence referents when he asks us to "assume for the time being that the sentence has a reference" (62).

Now let us examine Frege's reasoning for thinking that the referent of the sentence must be either the *True* or the *False*. Informally, it seems to me that Frege's argument goes something like this.¹²

(a) *SR*: Sentences are referring devices. Sentences *qua* singular terms may be regarded as proper names, and like proper names have both a sense and a reference (63).

(b) *Compositionality*: the referent of a complex referring expression is a function of the referents of its parts, whereas the sense of a complex referring expression is a function of the senses of its parts.¹³

(c) *SUB_{DES}*: Given (b), the referent of a compound referring expression – free of devices like quotation or “believes that” - is preserved when a component referring expression is replaced by another with the same referent.

(d) The referent of a sentence cannot be the thought (or proposition) it expresses since the thought (proposition) expressed by ‘The morning star is a body illuminated by the Sun’ differs from the thought expressed by ‘The evening star is a body illuminated by the Sun’. This is so given (c) and because ‘The morning star’ and ‘The evening star’ are coreferential.

¹² This argument reconstruction is developed from notes taken during a lecture given by A.C. Genova in the fall of 2007 at the University of Kansas. Cf. Genova (2001).

¹³ Following common parlance I use the term ‘compositionality’ in discussion of the Fregean notion. Care should be taken to avoid confusion with other, broader characterizations of compositionality in the philosophy of language and mind. For example, what’s often called “The Principle of Compositionality” gets articulated in the following way: the meaning of a complex expression is a function of its meaningful constituents [morphemes] and its syntactic structure”. The similarity between this broad notion of compositionality and the idea of Frege’s is evident, but the former discusses the relationship between expressions and meanings more generally, while the latter specifically concerns itself with the determination of the two semantic values of *sense* and *reference* and their relationship between respective bits of language. See Szabó (2001) and Fodor (2002) for lengthy discussions of the Principle of Compositionality in the philosophy of language and mind respectively.

(f) Whatever the referent of a sentence is, it must remain the same across coreferential substitutions – this includes subsentential expressions as well as full sentences themselves. Sentences with the same truth-value will be substitutable across all extensional contexts.

(g) IBE_{TV} : consequently, since the only semantically relevant thing about sentences that remains unchanged across substitution of coreferring expressions (in extensional contexts) is the truth-value, what else but the truth-value could be the referents of sentences?

The remaining discussion in “On Sense and Reference” focuses on various examples testing Frege’s thesis about the referents of sentences: the rather controversial initial assumption that sentences are similar enough to names to warrant applying the sense/reference distinction; an assumption about substitution to preserve reference given a reasonable principle of compositionality; and importantly even the makings of something similar to an abductive premise, which I label ‘ IBE_{TV} ’. Even if not formally represented, we can see that most of the assumptions required for a slingshot-style argument to proceed may plausibly be found within Frege’s reasoning. It is important to bear these Fregean considerations in mind when examining Church’s argument.

2.2.2 CHURCH’S SLINGSHOT¹⁴

Let’s turn to Church’s argument appearing in his 1943 review of Carnap’s *Introduction to Semantics* (appearing in the same year). This slingshot was a response to Carnap’s break with

¹⁴ My reconstruction of the Church argument is a version of what Tyler Burge (1986) calls a “standardized form”, though Burge notes that the argument “has a number of interesting variants, and...even more uses” (108). However, Burge notes that it is unlikely that Frege was giving an “elliptical” version of the Church-Gödel argument, since (by Burge’s interpretation) Frege “invokes the normative foundations of logic and the normative roots of the primacy of sentences in logical theory in arguing for this conclusion...The Church-Gödel argument makes no such appeal...” (109).

the Fregean view that sentences designate truth-values, opting instead for the alternative thesis that sentences designate propositions. Much of the argument, as should now be apparent, is inspired by Fregean considerations, in particular the recognition that Frege sought a theoretical analogue to singular term reference when constructing his own argument. Church's argument requires four relatively simple assumptions.

SUB_{DES}: The referent of a compound referring expression - absent nonextensional devices like quotation marks or "believes that" - is preserved when a component referring expression is replaced by another with the same referent.

SR: Sentences are referring expressions

ST: A class with the form, 'the ϕ ', refers to the only individual that satisfies the formula ϕ , if there is exactly one such individual and refers to nothing otherwise.

LED: Referring expressions that are logically equivalent to one another refer to the same thing.

I'll quickly remark on the two new assumptions. One may regard *ST* as an analogue of the Fregean assumption that sentences are complex names, but in the current case the expressions with which we are concerned are class abstractions. Note first that this assumption is in keeping with Frege's treatment of descriptions as referring devices, but second that the assumption is contrary to a Russellian descriptonal theory – one that treats descriptions as quantificational rather than referential devices. Now consider the assumption I label '*LED*'. Let us say that two singular terms α and β are logically equivalent if and only if ' $\alpha = \beta$ ' is logically true.¹⁵ By this

¹⁵ For example, consider 'The president's dog' and 'The president's self identical dog', both of which are logically equivalent; by *LED* these are also coreferential. David Kaplan (1964) remarks that this is a "seemingly gratuitous assumption" (13), though some like Barwise and Perry (1981) have disagreed. While rejecting *LED* is one way to avoid the slingshot's conclusion, I wish to focus on other ways the slingshot can misfire.

principle, logically equivalent referring expressions, whether names or definite descriptions, corefer.

Now consider the argument.

1. Assume SR and consider any two arbitrarily chosen sentences with the same truth-value, S and S' (e.g. S can be “Washington D.C. is the capital of the United States”, while S' may be “Aristotle founded the Lyceum”). (Note: the symbol ‘ Λ ’ stands for the null class).¹⁶
 - (a) S
 - (b) $\{x: x = x \ \& \ \text{not-}S\} = \Lambda$
 - (c) $\{x: x = x \ \& \ \text{not-}S'\} = \Lambda$
 - (d) S'
2. (a) and (b) refer to the same thing (by *LED*)
3. (c) and (d) refer to the same thing (by *LED*)
4. (b) and (c) corefer (by *SUB_{DES}* and *ST*)
5. So (a) and (d) refer to the same thing (1., 2., 4 and the transitivity of reference)

Repeating the argument with any pair of true sentences will deliver the result that all true sentences corefer. We could next run a similar argument, but this time instead of true sentences for S and S' we would use the falsities “New York is the capital of the United States” and “Plato founded the Lyceum” respectively. The result would be that all false sentences corefer. Thus, two quick, relatively simple slingshots get us the following *semantic* thesis: all true sentences refer to the same thing, while all false sentences refer to the same thing.

A few remarks about the reconstruction of the argument. Church’s original argument makes use of the lambda (λ) class abstraction operator, but I have opted for the simpler symbolization of class abstraction without use of the symbol “ λ ”. This is in accordance with

¹⁶ Church notes that instead of “ Λ ” one might also use the logically false, “ $(\lambda x)(\sim x = x)$ ” to the same effect.

Quine’s symbolization for class abstraction discussed in Section 2.3.1 below. I do retain Church’s use of the symbol, “ Λ ” for the empty class. The expression “ $\{x: x = x \ \& \ \text{not-}S\} = \Lambda$ ” can be read as “the class of things x which are such that $x = x$ and it is not the case that Washington D.C. is capital of the United States”. While the symbols “ S ” and “ S ” are not themselves well-formed formulae of first-order logic, they are used for purposes merely of simplification, and this usage is employed throughout the Slingshot literature. If preferred, simply substitute the arbitrarily chosen sentences when reading the expressions. What follows the occurrence of the colon, the “formula ϕ ” from ST, specifies the conditions under which something is a member of the class. Given the truth of the sentence S , “Washington D.C. is the capital of the United States”, the only individual satisfying the formula will be the null class. Later, in his *Introduction to Mathematical Logic* (1944) Church runs a similar argument, although this time he employs definite descriptions instead of class abstraction. So instead of ST, Church has something like the following in mind:

*ST**: A definite description with the form, ‘the ϕ ’, refers to the only individual that satisfies the formula ϕ , if there is exactly one such individual and refers to nothing otherwise.

This principle plays the same role as ST, although modified for definite descriptions. Davidson and the common noun Slingshot will make use of this principle as I discuss later.

Notice that in order to draw a metaphysical conclusion about what the referents of sentences *are* – say the Fregean position that sentences refer to truth-values – one will need a further premise, one perhaps similar to the one briefly mentioned above, along the following lines:

IBE_{TV}: The best explanation to account for the result of the slingshot is that all true sentences refer to a single unique entity *the true*, while all false sentences refer to a single unique entity, *the false*.

Without *IBE_{TV}* the slingshot is restricted to the more modest semantic thesis, namely that coextensional expressions are also codesignative, while remaining silent on what the referents of true and false sentences are. And though the this premise itself seems pretty reasonable, as far as the slingshot itself is concerned, one might take the argument to give equal support to the claim that all true sentences refer to say the number one, while all false sentences refer to the number zero or the null set.¹⁷

2.2.3 GÖDEL'S SLINGSHOT

Gödel's (1971) slingshot, like Church's, explicitly makes use of three assumptions similar to the one's invoked by both Church and Frege. Those assumptions are as follows:

Referential Compositionality – “the signification of a composite expression, containing constituents which have themselves a signification, depends only on the signification of these constituents (not on the manner in which this signification is expressed)”

*LED** – $\langle \phi \alpha \rangle$ and $\langle \alpha \rangle$ is the object which has the property ϕ and is identical with α (in Gödel's words) “means the same thing” [sic] (Gödel 122).¹⁸

¹⁷ To this end one might construct a similar abductive alternative: *IBE_{NO}*: The best explanation to account for the result of the slingshot is that all true sentences refer to a single unique entity *the number one*, while all false sentences refer to a single unique entity, *the null set*.

¹⁸ Neale (2001) remarks that “[*LED**] is less worrying than Gödel's wording might suggest” (130), though he does not go on to say why he thinks this. Later, Neale writes, “An examination of the main text...might suggest that [Gödel] intends ‘signify the same thing’. Whatever Gödel's intention, for the purposes of this argument I shall attribute to him it is both sufficient and necessary that if descriptions are singular terms that simply stand for things, then $\langle \phi \alpha \rangle$ and $\langle \alpha \rangle$ is the object which has the property ϕ and is identical with α] stand for the same fact” (130). I disagree Neale's latter characterization, mainly because of the use of the phrase “stand for the

*SR**: “Every Proposition ‘speaks about something’, i.e., can be brought to the form $\phi(\alpha)$. Furthermore one would have to use the fact that for any two objects a, b , there exists a true proposition of the form $\phi(a, b)$ as, e.g., $a \neq b$ or $a = a.b = b$ ” (122).

Though Gödel’s wording deviates from Church’s language, many of his assumptions do the same theoretical work. First, the assumption above labeled “Referential Compositionality” presumably does the work of Church’s substitution assumption. Second, Gödel’s assumption *LED**, though seemingly worrisome, is likely best interpreted along the lines of *LED*, that logically equivalent referring expressions refer to the same thing.¹⁹ Third, I take *SR** as a syntactic articulation doing the work of *SR* above. Fourth, just as Church requires an assumption about the uniqueness of referents for class abstractions, Gödel will need an analogous principle for definite descriptions. Finally, just as Church’s slingshot needs a further premise to get to an ontological conclusion about truth-values, so does Gödel, though Gödel’s language is careful to conclude only that, “all true sentences have the same signification (as well as all the false ones)” (122). Gödel leaves readers to piece through the argument for themselves (as the hints of the argument are made only in a footnote), though the reasoning runs the same as the Church deployment. Let us now turn to more contemporary slingshot deployments. As we will see, these slingshots draw far more robust metaphysical conclusions.

same fact”, for Gödel never mentions the term “fact”. I find it more plausible to interpret the phrase “means the same thing”, along the lines of Neale’s earlier proposal as “signify the same thing”, since this is Carnap’s (1959) characterization of synonymy (55) and it’s reasonable to think that Gödel was familiar with this fact.

¹⁹ Cf. footnote 18 above.

2.3 QUINE, DAVIDSON, AND COMMON-NOUN SLINGSHOTS²⁰

There are important distinctions between the slingshots presented by both Church and Gödel and those I am about to discuss. One key difference is one of presentation, as both Quine and Davidson present their arguments in the form of a *reductio*. Quine’s targets are purportedly “opaque contexts”, i.e. intensional contexts involving words like “necessarily” and “possibly”, and hyperintensional contexts involving propositional attitude terms like “believes”, “wishes”, “wants”, etc.²¹ Davidson’s various slingshot deployments serve several different purposes, the most widely discussed being his famous argument against traditional correspondence theories of truth that make use of facts as truth-makers for sentences. Let’s begin with the assumptions Church uses in his version of the argument – SUB_{DES} , SR, ST, and LED – and turn first to discussion of Quine.

2.3.1 QUINE’S SLINGSHOTS

Quine’s first slingshots appear in “Reference and Modality” (1956) in the first edition of *From a Logical Point of View* (2nd ed. Reprinted in 1961), and in his “Three Grades of Modal Involvement” (reprinted in 1975, but originally appearing in 1953), while another occurs in 1960 in *Word and Object*. All versions of the argument may be interpreted to the same end: to cast doubt on the intelligibility of ostensibly nonextensional contexts. I shall focus on the one from 1953 in “Reference and Modality”.

²⁰ One other slingshot receiving little to no discussion in the literature may be found in footnote 71 of David Kaplan’s essay on demonstratives from 1977 (republished in Davidson 2007). This slingshot deployment like those of Quine and Davidson takes the form of a *reductio* with the aim of showing that certain substitution moves are not legitimate for *pseudo de re* contexts.

²¹ Quine uses the term “intensional” to describe both modal and hyperintensional contexts alike, though overall it appears he is concerned with contexts that appear to result in some failure of substitution. I will simply use the expression “nonextensional” when referring to such contexts.

More generally, Quine (1961) claims that his slingshot allows him to make a more “sweeping observation”, that “*any* mode of statement composition other than the truth functions, is referentially opaque” (159).²² In order for this conclusion to sound even remotely plausible, Quine needs two variants on the principles of Frege and Church:

SUB_{TV}: The truth-value of an expression is preserved when a component expression is replaced by another with the same truth-value.

LES: Logically equivalent expressions may be substituted in all contexts *salva veritate*.

The other assumption needed is *ST*, which for Quine’s purposes does not depart significantly from the one stated above. Quine’s aim is to show that *SUB_{TV}* does not extend to expressions containing non-truth-functional operators that still allow *LES*. Restated in Quine’s own words, his aim is to show that non-truth-functional expressions are “referentially opaque”. Notice that *SUB_{TV}* omits the extensional restriction, as this will be a bone of contention I discuss later in this essay. So let Φ be a purportedly non-truth-functional expression such as ‘necessarily’ or ‘possibly’, and assume for *reductio* that *SUB_{TV}* applies to sentences containing Φ , for then it will follow that Φ is truth-functional, a presumably unacceptable result. So let *S* and *S’* be any two arbitrarily chosen sentences alike in truth-value, say ‘Hesperus is Hesperus’ and ‘Quine was born in Akron’. Suppose further that Φ is ‘necessarily’. Then if $\Phi(S)$, then $\Phi(S')$, or if ‘Necessarily, Hesperus is Hesperus’, then ‘Necessarily, Quine was born in Akron’.

- | | |
|---|---|
| 1. $\Phi(S)$ | Assumption |
| 2. $\Phi(\{x: x = x \ \& \ S\} = \Lambda)$ | 1., <i>LES</i> |
| 3. $\Phi(\{x: x = x \ \& \ S'\} = \Lambda)$ | 2., <i>SUB_{TV}</i> , <i>ST</i> |
| 4. $\Phi(S')$ | 3., <i>LES</i> |

²² Emphasis is Quine’s.

Going back the other direction would yield $\neg\Phi(S)$ if and only if $\Phi(S')$. Presumably this conclusion is an unacceptable result unless, as Quine states, “the context represented by ‘ Φ ’ is referentially opaque” (159). However, referential opacity according to Quine is problematic since trouble arises when one attempts to quantify into nonextensional contexts.²³ Thus, Quine’s reasoning appears to be that if we treat purportedly nonextensional expressions as truth-functional, then a slingshot delivers unacceptable results, while if we accept nonextensional expressions as indeed nonextensional, we risk the incoherence of quantifying into them.²⁴

As we saw above, in order for this variant of the slingshot to seem plausible at all, Quine must modify the assumptions used by Church and Frege; such close approximations might slip by the unwary reader. Thus, Quine’s slingshot with its two variants of the principles discussed earlier, SUB_{TV} and LES , its *reductio* form, and the conclusion it draws represents a significant departure from the original reasoning employed in Frege, Church, and Gödel. We will return to these differences later. For now, let us turn to discussion of Davidson’s slingshots.

2.3.2 DAVIDSON’S SLINGSHOTS

To my knowledge there are at least three separate slingshots in the work of Davidson, all of which share an affinity with Quine’s formulations in taking the characteristic *reductio* form. The first two appear in 1967. One appears in “Truth and Meaning” (2001b) (19) where Davidson uses the slingshot as a way to show that expressions cannot refer to their meanings

²³ The argument for why quantifying into nonextensional contexts is unintelligible is hinted at in Quine (1953), but is spelled out in more explicit detail in Quine (1956).

²⁴ The Kronecker δ version from Quine (1960: 148 - 149) is employed much to the same effect as the earlier 1953 version, but this time using propositional attitude contexts instead. So, where Φ is a propositional attitude operator such as ‘believes that’, the result would be that the subject of the sentence ends up believing everything. Unless of course ‘believes that’ is referentially opaque.

since the slingshot would show that all expressions with the same semantic extension end up having the same meaning, a clearly unacceptable result.²⁵ The other in “The Logical Form of Action Sentences” (2001a) (117 – 118) raises an objection to Reichenbach’s (1947) analysis of the logical form of action sentences. According to Davidson, if one adopts Reichenbach’s proposal, a quick slingshot shows that there is but one event, and so by *reductio* Reichenbach’s view must be false. Finally, perhaps the most famous of the three is the slingshot in “True to the Facts” (2001b) where Davidson uses the slingshot to object to Correspondence theories of truth that make use of facts as the truth-makers of sentences. If sentences designate facts, Davidson maintains, then all true sentences designate the same fact. Since this Eleatic conclusion is unacceptable, the initial presupposition about sentences designating facts must be false, *reductio ad absurdum*. While I will focus on the argument as it appears in “True to the Facts”, the expository and critical remarks I make about that argument may be applied *mutatis mutandis* to the argument from “The Logical Form of Action Sentences”.²⁶

²⁵ The first Slingshot appearance in “Truth and Meaning” is relevant for my purposes only to the extent that the conclusion reached is actually quite plausible, namely that there must be more to meanings than extensions. Admittedly, Davidson puts forward this version as a formalized version of the arguments of Frege and Church. Since those arguments have already been discussed, there is no need to go into discussion as to whether Davidson’s interpretation of them is correct.

²⁶ Critically, what I mean is that both arguments contain expressions with occurrences of “the fact that”, which I discuss below. I would however like to point out another observation about Davidson’s Reichenbach criticism. Reichenbach’s proposed analysis for the logical form of an action sentence such as “Amundsen flew to the North Pole in May 1926” would according to Davidson look as follows

($\exists x$) (x consists in the fact that Amundsen flew to the North Pole in May 1926)

Davidson’s move is then to substitute any other sentence with the same truth-value for “Amundsen flew to the North Pole in May 1926” in the same manner as other slingshots allow for intersubstitutability. But this argument has a more obvious vulnerability, which is that the existential quantifier takes scope over the entire subsequent expression. In other words, Reichenbach’s proposal is to treat action sentences as existentially quantified expressions, much

Davidson begins by asking when statements with the following form hold:

(3) the statement that p corresponds to the fact that q

His response is as follows:

Certainly when “ p ” and “ q ” are replaced by the same sentence: after that the difficulties set in. The statement that Naples is farther north than Red Bluff corresponds to the fact that Naples is farther north than Red Bluff, but also it would seem, to the fact that Red Bluff is farther south than Naples (perhaps these are the same fact). Also to the fact that Red Bluff is farther south than the largest Italian city within thirty miles of Ischia. When we reflect that Naples is the city that satisfies the following description: it is the largest city within thirty miles of Ischia, and such that London is in England, then we begin to suspect that if a statement corresponds to one fact, it corresponds to all (2001b 41 – 42).

Next Davidson turns to spelling out the reasoning employed in the above excerpt. The two assumptions he provides explicitly are as follows:

(4) the sentences that replace ‘ p ’ and ‘ q ’ are logically equivalent

(5) ‘ p ’ differs from ‘ q ’ only in that a singular term has been replaced by a coextensive singular term

Although these suppositions as stated are not themselves principles, it’s easy enough to turn them into principles similar enough to the ones already discussed. Thus (4) appears to do the work of the assumption above *LED*, namely that logically equivalent referring expressions

like Russell’s treatment of definite descriptions. As I remarked earlier in the essay, Neale points out that Russell’s would-be move to avoid Eleatic collapse is to *deny* that quantified expressions are singular terms. In effect, Russell denies the premise I earlier called *ST** which claimed that definite descriptions are referring expressions. A similar move appears available to Reichenbach as well.

²⁶ While the first slingshot in “Truth and Meaning” is interesting within the context of that essay, since the conclusion reached is far more plausible than Davidson’s other uses of the argument, namely that there must be more to meanings than extension, discussion on this version can for the most part be ignored. What’s more, this version is put forth as a formalized version of Frege and Church’s arguments. For my purposes, however, it’s the questionable cases that are of interest.

corefer, while it's likely that (5) does the work of SUB_{DES} . Though not mentioned, presumably Davidson also needs something like ST , but this time modified for the case of definite descriptions, i.e. the assumption that descriptions of the form 'the fact that ϕ ' are designators. This is what I earlier called ST^* . Now consider any two arbitrarily chosen sentences that have the same truth-value, p and q , and consider the following slingshot:

1. the fact that p
2. the fact that $(\lambda x)(x = \text{Diogenes} \ \& \ p) = (\lambda x)(x = \text{Diogenes})$
3. the fact that $(\lambda x)(x = \text{Diogenes} \ \& \ q) = (\lambda x)(x = \text{Diogenes})$
4. the fact that q

Davidson's reasoning then proceeds in typical slingshot fashion: 1 and 2 are codesignative by LED ; 3 is codesignative with 2 by SUB_{DES} and ST^* ; 3 and 4 are codesignative by LED . Thus, 1 and 4 are codesignative. If we generalize with the result from the conclusion, we get the desired Eleatic conclusion: all descriptions with the form 'the fact that ϕ ' designate the same fact.

This concludes the discussion on what we might call the "classic" slingshot deployments. However, before I turn to the final section, there is one more suspect slingshot to discuss, one proposed by Nathan Salmon (2005) concerning the referents of common noun phrases.

2.4 A SLINGSHOT FOR COMMON NOUNS

This sub-section considers argument one might propose to support the view that kinds are individuated by their metaphysical extensions. The argument for this view, one I'm calling the *extensional view* of kind individuation, takes the conclusion from a common noun slingshot, that for any arbitrarily selected pair of common nouns happening to share the same semantic extension, those two nouns corefer. Generalizing to other common noun pairs yields the conclusion that common nouns with the same semantic extension corefer, which may then be

used to formulate an argument for the individuation of kinds. The specifics of such an argument needn't be articulated in much detail here since my intent is to nip any such argument in the bud by showing how a slingshot of this form fails.

Along these lines, one might construct a slingshot argument in the vein of Church and Gödel to argue for the claim that any two arbitrarily chosen common nouns that happen to have the same extension refer to the very same thing. If sound, the argument would strongly suggest that any two common nouns that happen to have the same semantic extension, e.g. ‘Tyrannosaurus rex’ and ‘dodo’, refer to the same thing.

The argument requires the same assumptions from the original Church version above, though with two minor changes, ν -*SUBS* and *CNR*. The former is simply our good old original *SUB_{DES}* reformulated to accommodate common nouns. The latter just states that common noun phrases are referring expressions. Salmon (2005) also employs a device that turns an open sentence like “ x is striped and eats meat” into a common noun phrase using the phrase “thing which is such that” which functions as a variable binding operator to obtain the closed expression “thing which is such that it is striped” (50 – 51).

Assumptions²⁷

ν -*SUBS*: The referent of a compound referring common noun phrase – free of devices like quotation or “believes that” - is preserved when a component referring expression is replaced by another with the same referent.

CNR: Common noun phrases are referring expressions

*ST**: A definite description ‘the ϕ ’ refers to the only individual that satisfies the formula ϕ , if there is exactly one such individual and refers to nothing otherwise.

²⁷ This argument is adapted from Salmon (1991) and Salmon (2005: 48 – 52).

LED: Referring expressions that are trivially logically equivalent to one another refer to the same thing.

Preliminaries

Let v and v' be any two (arbitrarily chosen) common nouns that have the same extension (e.g. ‘*T-rex*’ and ‘dodo’ or ‘molecule of water’ and ‘molecule of H_2O ’).

The Argument

1. Assume *CNR* and consider:
 - (a) v
 - (b) thing x such that $(\iota n)[\text{if } x \text{ is a } v, \text{ then } n = 1) \ \& \ (\text{if } x \text{ is not a } v, \text{ then } n = 0)] = 1$
 - (c) thing x such that $(\iota n)[\text{if } x \text{ is a } v', \text{ then } n = 1) \ \& \ (\text{if } x \text{ is not a } v', \text{ then } n = 0)] = 1$
 - (d) v'
2. (a) and (b) refer to the same thing by *LED*.
3. (c) and (d) refer to the same thing also by *LED*.
4. $(\iota n)[\text{if } x \text{ is a } v, \text{ then } n = 1) \ \& \ (\text{if } x \text{ is not a } v, \text{ then } n = 0)]^\dagger$ and $(\iota n)[\text{if } x \text{ is a } v', \text{ then } n = 1) \ \& \ (\text{if } x \text{ is not a } v', \text{ then } n = 0)]^\dagger$ are coreferential by *ST** since both are set equal to 1.
5. So (b) and (c) have the same referent [4., *SUB_{DES}*].
6. So (a) and (d) have the same referent [2, 3, 5].

Thus, we have to means to run this argument to draw the conclusion that any two common nouns with the same semantic extension corefer. Like other slingshots, this conclusion only delivers a semantic conclusion, one telling us only that for any two arbitrarily chosen common noun phrases that happen to have the same extension, those noun phrases have the same referent; the argument itself tells us nothing about what the referents of those expressions are.

It should be noted that Salmon (2005) thinks the argument is unsound since line 5 makes an illegitimate appeal to *v-SUBS*: If the argument were sound, so Salmon reasons, the phrases “neighbor of Shakespeare” and “neighbor of England’s greatest playwright” would refer to one

and the same kinds.²⁸ However, this seems wrong since “it is easy to imagine circumstances in which there are individuals who are of one kind but not the other” (52). Unfortunately, this is the only explanation given in *Reference and Essence* for rejection of *v-SUBS*. Though we are told rejecting *v-SUBS* is the reason for the trouble, I suspect that flat out rejection of the principle is a little too hasty. In fact, I think the reasoning employed in rejecting the sort of substitution move involved in the common noun slingshot has to do with the context created by the phrase “thing *x* such that”. Salmon acknowledges this fact in later essays and it’s likely the idea he had in mind (albeit implicitly in his earlier work) in rejecting *v-SUBS*.²⁹

There is one final topic to address before moving on to criticisms, namely substitution rules. All slingshots require some form of substitution, whether the substitution is intended *salva designate*, to preserve the referent of the larger containing expression, or *salva veritate*. Such a key move needs a brief discussion since the legitimacy of certain slingshot deployments hinges on which substitution moves are acceptable.

2.5 SUBSTITUTION RULES³⁰

Here I will discuss various substitution principles commonly found in extensional logic. This will be helpful in reminding readers of Frege’s and Church’s motivations for developing their substitution analogues, provided one is careful to remember that the Frege-Church-Gödel versions were concerned with substitution *salva designate* rather than truth-preservation. As

²⁸ What I’m calling “*v-SUBS*” Salmon calls the “*Interchange Principle for Common Nouns*” (52).

²⁹ See for instance Salmon (2001).

³⁰ This section borrows significantly from Neale (2001) Chapter 7 and I adopt Neale’s symbolization in stating the proceeding rules. There is however one addition, *Nu-Substitution*, which is a formal representation of Salmon’s (2005) *Interchange Principle for Common Nouns*. One other significant departure from Neale is that I prefer not to discuss these as *inference* rules, but rather rules concerning legitimate substitution, *salva designate*.

such, certain principles concerned with referent preservation ought therefore to be regarded as a class of principles separate from typical principles of inference. Inference principles, as any student of introductory symbolic logic will attest, *are* truth-preserving rather than referent preserving. In articulating many of the principles found below, however, I shall speak loosely of inference, though it is important to remember that slingshot substitution principles are but *analogues* to principles of inference.

PSME: *Principle of Substitutivity for Material Equivalents*

$$\frac{(\phi \equiv \psi) \quad \Sigma(\phi)}{\Sigma(\psi)}$$

We can read this as saying that for any two sentences ϕ and ψ sharing the same truth-value, where $\Sigma(\phi)$ is a true sentence containing at least one occurrence of ϕ (in an extensional context), we can legitimately infer $\Sigma(\psi)$, where $\Sigma(\psi)$ is the result of replacing at least one occurrence of ϕ in $\Sigma(\phi)$ by ψ and vice versa. As is familiar, a linguistic context is extensional just in case it permits the substitution of coextensional expressions such that the truth of the larger containing expression is preserved. Consider:

- (a) Quine was born in Ohio and Davidson was born in Massachusetts

The binary connective ‘and’ (along with the other usual truth-functional connectives) is extensional in the sense that it operates on the extensions of sentences, namely truth-values. Thus, the truth of (a) is preserved if we substitute for either of the sentences flanking ‘and’ with another true sentence, e.g. “Kripke was born in Nebraska”.

PSST: *Principle of Substitutivity for Singular Terms*

$$\frac{\alpha = \beta \quad \Sigma(\alpha)}{\Sigma(\beta)} \quad \text{or} \quad \frac{\Sigma(\alpha) \quad \sim \Sigma(\beta)}{\sim \Sigma(\beta)}$$

$$\Sigma(\beta) \qquad \alpha \neq \beta$$

We can read this principle as saying that if one has two coextensional singular terms α and β , where $\Sigma(\alpha)$ is a sentence containing at least one occurrence of α (in an extensional context), then one may infer $\Sigma(\beta)$, where $\Sigma(\beta)$ results from replacing α in $\Sigma(\alpha)$ by β , and vice versa. So consider:

(b) Venus revolves around the sun

In (b) we may substitute for the proper name ‘Venus’ the coreferring proper name ‘Hesperus’ to obtain

(c) Hesperus revolves around the sun

One bit of contention surrounding this principle is the question of what sorts of expressions are included among the class of singular terms. Some, such as Frege, include definite descriptions in this class, while others like Russell did not. Thus, Frege would allow the move from

(d) Hesperus is Phosphorus

to

(d') The evening star is Phosphorus

provided of course that (d) and (d') are not themselves embedded in nonextensional contexts.

Russell on the other would not treat (d') as a singular term, asserting instead that it should be given a quantificational analysis (see footnote 1 above).

PSLE: *Principle of Substitutivity for Logical Equivalents*

$$\frac{\phi \Leftrightarrow \psi \quad \Sigma(\phi)}{\Sigma(\psi)}$$

Let us say that two expressions ϕ and ψ are logically equivalent if and only if the sentence $\phi \Leftrightarrow \psi$ is logically true, where ‘ \Leftrightarrow ’ is to be understood as symbolizing dual entailment. So this

principle can be read as saying that if two expressions ϕ and ψ are logically equivalent and $\Sigma(\phi)$ is a true sentence containing ϕ as a constituent (in an extensional context), then $\Sigma(\psi)$ will also be true, where $\Sigma(\psi)$ results from replacing ϕ in $\Sigma(\phi)$ with ψ and vice versa. By this principle we can move from

(e) The President's dog is black

to

(e') The President's self-identical dog is black

This principle is particularly important for slingshot-style arguments, as many have contested the principle's legitimacy in criticizing slingshot deployments.

ι -SUBS: *Iota-Substitution (Principle of Substitutivity for Definite Descriptions)*

$\iota x\phi = \iota x\psi$	$\iota x\phi = \alpha$	$\iota x\phi = \alpha$
$\Sigma(\iota x\phi)$	$\Sigma(\iota x\phi)$	$\Sigma(\alpha)$
$\Sigma(\iota x\psi)$	$\Sigma(\alpha)$	$\Sigma(\iota x\phi)$

For those who accept definite descriptions as singular terms, these substitution rules will be superfluous since PSST already directly licenses these moves. However, for those who adopt a Russellian treatment of descriptions, PSST will not work. Consider

- (f)
- i. Kripke = the greatest philosopher from Omaha
 - ii. Kripke authored *Naming and Necessity*
-
- iii. The greatest philosopher from Omaha authored *Naming and Necessity*

It's clear that (f) is a valid argument, but if we were to formalize it we cannot use our principle about singular terms, PSST, to make the move (assuming of course a Russellian theory of descriptions):

- (f')
- i. $k = (\iota x)Ox$ premise
 - ii. Nk premise

iii. $N(\iota x)Ox$

i, ii, PSST

Iota-Substitution, however, resolves this problem; rather than using PSST as the justification at iii, one can appeal to ι -SUBS. This triple of rules says that first, if the unique individual satisfying the constitutive formula ϕ is the same as the unique individual satisfying the constitutive formula ψ , one can substitute $\iota x\phi$ for $\iota x\psi$ and vice versa. Second and third, if the unique individual satisfying the constitutive formula ϕ is the same individual denoted by the singular term α , then one may substitute (in extensional contexts) $\Sigma(\alpha)$ for $\Sigma(\iota x\phi)$, where $\Sigma(\alpha)$ is the result of replacing α for $\iota x\phi$ in $\Sigma(\iota x\phi)$ and vice versa.

ν -SUBS: *Nu-Substitution (Principle of Substitutivity for Common Nouns)*

$$\begin{array}{ccc} \alpha = \beta & \text{or} & \tau(\alpha) \\ \tau(\alpha) & & \sim\tau(\beta) \\ \hline \tau(\beta) & & \alpha \neq \beta \end{array}$$

In keeping with the Fregean spirit of maintaining the analogy with singular term reference, one might construct a principle for the interchange of common noun phrases. We can read this principle as saying that if two coextensional singular terms α and β are identical (i.e. ' $\alpha = \beta$ ' is true), where $\tau(\alpha)$ is a common noun phrase containing at least one occurrence of α (in an extensional context), then one may infer $\tau(\beta)$, where $\tau(\beta)$ results from replacing α in $\tau(\alpha)$ by β , and vice versa.

Earlier I mentioned that Salmon (2005) suggests a rejection of ν -SUBS, and that a flat out rejection of the principle seems too quick. The trouble in the common noun slingshot seems to be caused not by the principle itself, but by the phrase "thing x which is such that", in particular

the “that” operator, which Salmon in later essays maintains is arguably nonextensional.³¹ If indeed the “that” operator is nonextensional, then slingshots that make the substitution moves for expressions within the scope of these operators have ignored the caveat that substitution is licensed only for extensional contexts. This move is perhaps the most frequently occurring dubious strategy in slingshot deployments.

2.6 SLINGSHOT MALFUNCTIONS

I now turn to discussion of some common slingshot malfunctions.

2.6.1 THE EXTENSIONAL MALFUNCTION

Arguments without the extensional restrictions on substitution go awry in that there is an illegitimate appeal to a substitution principle *very similar* to a legitimate one, although the principle itself in its unqualified form is strictly speaking false.³² Consider the original formulation of our substitution principle:

SUB_{DES}: The referent of a compound referring expression – *free of devices like quotation or “believes that”* – is preserved when a component referring expression is replaced by another with the same referent.

³¹ See for example Salmon (1991: 6) and Salmon (2001: 349). One potential hiccup for Salmon’s hypothesis is that contexts typically regarded as opaque, e.g. propositional attitude contexts like “believes that” or modal contexts like “it is necessary that”, are opaque because of operators like “believes” or “It is necessary” rather than the “that”. The reply is that this seems wrong if we consider expressions like “Russell affirmed Logicism”, which omits the occurrence of “that” while remaining perfectly grammatical. Further, from the truth of this statement one can infer the following: Russell affirmed that mathematics is reducible to logic. That the “that” operator is nonextensional seems to me a plausible hypothesis. But then what about expressions like “it’s not the case that”? If anything is an extensional operator, surely this is. Salmon’s reply (in e-mail correspondence) is that the expression “the case” is synonymous with “true”, and that “It is the case that snow is white” is a stylistic variant of “That snow is white is the case”. Similarly, “It is not the case that snow is white” is a variant of “That snow is white is not the case”, which express the proposition *that snow is white is not true*.

³² Philosophers who propose the argument either without or who fail to adhere to the extensional restriction include Barwise and Perry (1981), Davidson (2001a, 2001b, 2001c), McGinn (1976), Perry (1996), and Quine (1960, 1961).

Preservation of reference for a larger containing expression when substituting coreferring constituent expressions is preserved only when those constituent expressions are not within the scope of ostensibly nonextensional, or *ungerade*, contexts. As I discussed earlier, even Frege himself was careful to include a clause about the principle's inapplicability for cases involving direct or indirect quotation.³³

But now consider Quine's slingshots in light of this restriction, both of which involve substitution of coreferring expressions under the scope of what Quine claims are purportedly nonextensional operators such as "it is necessary that" or "believes that". Given the extensional restriction on substitution principles, Quine's slingshots might strike one as odd, but recall that SUB_{TV} as I formulated it did away with this restriction. Also remember that Quine's aim is to show that accepting SUB_{TV} along with the other assumptions listed earlier delivers the result that supposed nonextensional operators in fact turn out to be extensional, which is evidently unacceptable. Quine's further result, that supposed nonextensional bits of language are simply incoherent, is obviously not delivered by this slingshot, and must be argued for elsewhere.³⁴

But the trouble for the Quinean deployments, as well as other slingshots utilizing the *reductio* model, is that the strength of a *reductio* relies on the assumption that all other premises in the argument are true. So imagine that the Quinean supporter replies that the question of which substitution moves are legitimate principles for slingshot-style argumentation is precisely what is at issue, and that deciding which contexts are applicable to various substitutions in advance stacks the deck unfairly against the Quinean argument. However, if one can reject a premise other than the *reductio* premise, and in our current case it is at least *plausible* that the

³³ Admittedly, neither Church nor Gödel explicitly include a clause restricting the principle to extensional contexts, although neither attempts to use a slingshot with such devices either.

³⁴ E.g. In Quine (1956).

principle that's false is not the *reductio* premise but the unqualified restriction principle, the whole argument is significantly weakened.

Let's now turn to the Davidson slingshot about facts. Recall that Davidson's goal was to cast doubt on correspondence theories that made use of facts, and that the slingshot supposedly shows that all facts collapse into one great Eleatic fact. However, Davidson's slingshot also contains a questionable context, viz. "the fact that...", arguably nonextensional due to the occurrence of the "that" operator. Since Davidson's slingshot about facts also employs the characteristic *reductio* form, his argument, like the Quinean deployment, is significantly weakened. For the proponent of facts may just as easily reject Davidson's substitution principle while maintaining that sentences still correspond to facts.

Finally, what of the common-noun slingshot from Salmon (2005)? Again, like the Quinean and Davidsonian versions, the common-noun slingshot makes use of an arguably non-extensional context with the operator "thing which is such that". Unlike the Quine and Davidson slingshots, however, the common noun slingshot does not make use of the *reductio* form, and so the criticism against those previous deployments does not apply here. That the proposed phrase appears analogous with other non-extensional devices like modal and propositional attitude operators is sufficient to regard the move with suspicion.

Thus, in order to derive the intended disquieting conclusions from these slingshots, the arguments must include a premise that is at least arguably contestable. This strategy should strike the reader as highly methodologically suspect.

Suppose, however, an advocate of the *reductio*-style slingshot of Davidson's simply grants that the "that" operator is nonextensional. There is another way to read Davidson's

slingshot that need not appeal to a contestable, purportedly nonextensional context like “the fact that”. Consider the original Church slingshot and its four assumptions. As a reminder:

SUB_{DES}: The referent of a compound referring expression – free of devices like quotation or “believes that” – is preserved when a component referring expression is replaced by another with the same referent.

SR: Sentences are referring expressions

*ST**: A definite description ‘the ϕ ’ refers to the only individual that satisfies the constitutive “predicate” (or formula) ϕ , if there is exactly one such individual (and refers to nothing otherwise).

LED: Referring expressions that are trivially logically equivalent to one another refer to the same thing.

However, suppose one were to replace *SR* with a variant that we assume for *reductio*

SF: Sentences correspond to facts

If we now run the slingshot as Church did, the Eleatic conclusion appears to follow, and the critic of facts may now claim that *SF* is the premise causing the trouble, for we now no longer have substitutions that take place within a context like “the fact that”.

But what this reconstruction of Davidson’s slingshot does suspicious for two reasons. First, it makes the contentious assumption that the correspondence relation is the same as reference.³⁵ Second, and more importantly for our purposes, it builds into an ostensibly semantic

³⁵ I flag this as contestable move, though for the purpose of this essay, the point is not all that crucial. I would however like to say a little about why collapsing reference to correspondence is at least arguably illegitimate. Historically, both Frege and Mill are notable for distinguishing between the *referent* of an expression on the one hand, and the *content* on the other. Contemporary advocates of Millianism also make a similar distinction, though for certain sorts of expressions – e.g. demonstratives, indexical expressions, and proper names – content and reference are the same. Slingshots, as we’ve noted, are arguments concerned with the referent, or designata of expressions, rather than their content. What’s more, consider the fact that a

argument a fairly substantive and highly suspicious metaphysical assumption about facts. This strategy represents a significant deviation from the original Frege-Church-Gödel slingshots.

2.6.2 DUBIOUS METAPHYSICAL PREMISES

This malfunction involves building dubious metaphysical assumptions into the argument in order to draw dramatic metaphysical conclusions. The original slingshot deployments, those by Frege, Church, and Gödel, by themselves established only the semantic thesis that sentences with the same truth-values have the same designation. A more general conclusion may be drawn with the slingshot and expressions other than sentences, namely that the closest thing to singular term reference for *any* expression will be the expression's extension. Any further metaphysical conclusions can be reached only by adding one or more substantive metaphysical assumptions, for example by way of adding an abductive premise, as with Frege and Church. That assumption may look similar to what I earlier called IBE_{TV} .

IBE_{TV} : The best explanation to account for the result of the slingshot is that all true sentences refer to a single unique entity *the true*, while all false sentences refer to a single unique entity, *the false*.

As briefly mentioned earlier, the conclusion of the slingshot (if sound) seems equally compatible with a variant of IBE_{TV} where the referents of sentences are say the number one and zero or the empty set. However, recognizing that the slingshot is an argument concerning the relationship between bits of language and their relations to various semantic values, there is reason to favor

theory of content, and so too with the notion of correspondence, seeks to preserve certain structural features between an expression, and what that expression is supposed to represent. This mirroring, isomorphism or paralleling, is not something typically associated with reference.

IBE_{TV} over a principle invoking numbers since it's difficult to see the initial semantic relevance of numerical entities to whole sentences.³⁶

Similarly, the second reconstruction of Davidson's slingshot builds into the assumptions of the argument a rather substantive answer to what the referents of sentences are, namely facts. But this should strike one as a dubious methodological strategy. I can use the slingshot in this way to prove there's only one fact, one truth, one proposition, but only if I build entities into the assumptions needed for the argument to work. Presumably the rationale behind Davidson's questionable assumption rests on the idea that a correspondence theorist must say that sentences correspond to facts, and that the relation of correspondence is the same as reference. This ignores the possibility of linguistic expressions relating to objects in other ways. For even Frege notes that while the sense of an expression cannot be the reference, we still might say that a sentence *expresses* its sense and *refers* to its referent. This same Fregean strategy seems open to one who would like to avoid the Davidson slingshot.

2.7 A LESSON FROM MISFIRED SLINGSHOTS

I began with an examination of the historical roots of slingshots with the hope that an understanding of the original motivations of the argument's authors would give us insight into later versions of it. I then examined a variety of slingshot deployments with a special focus on those whose conclusions were of significance for metaphysics. Those metaphysically oriented slingshots I argued made use of several methodologically suspect strategies. These dubious strategies came in two main varieties: first, extensional malfunctions as we saw in Quine, Davidson, and one discussed (but not endorsed) by Salmon; and second those deployments whose metaphysical assumptions were to blame for generating the shocking conclusions. These

³⁶ Numbers will be relevant if we're inquiring after the referents of numerals.

suspicious strategies, I argued, make certain slingshot deployments far less metaphysically significant than they might at first appear. The larger lesson to be learned from this concerns the relationship between linguistic considerations and metaphysics, where I urged caution when drawing metaphysical conclusions from semantic arguments.

Of course we cannot conclude from this that there are *no* metaphysical conclusions to be had from linguistic considerations like the slingshot, although I think my remarks here give us reason to be skeptical of such attempts, particularly when the conclusions drawn appear to be so utterly earth-shattering. I have also not argued that the slingshot is itself uninteresting. To the contrary, the argument is interesting insofar as it (i) gives us very strong (though not decisive) evidence for the claim that the designatum of any expression is its semantic extension or that (ii) certain sorts of linguistic contexts require substitution restrictions on pain of generating absurd results. These, however, are interesting *semantic* results; they tell us very little (if anything) about metaphysics.

Essay 2

3. ON BEHALF OF STRUCTURAL UNIVERSALS

3.1 INTRODUCTION

In the previous essay the discussion revolved around philosophical methodology in the philosophy of language, and how many famous deployments of Slingshot arguments make use of suspicious tactics. The Slingshot's alleged relevance to the metaphysical question of what natural kinds are came from the proposal to use a Slingshot-style argument in order to argue for a very minimalist theory of natural kinds, one which holds that natural kinds just are classes. In criticizing that argument, along with the assumption that a theory of natural kinds needs an account beyond that of the Extensionalist View, we're now left with the question of how to give a more detailed account of some version of the Intensionalist theory. This essay will defend the idea that *structural* considerations are important for the question of kind individuation.

To illustrate by what I mean by "structure", consider Ernest Bloch's *Suite for Viola and Orchestra*. This piece is not identical with any token performance of it. Nor is it identical with the marks on a page of sheet music. Nor is the piece identical with some particular recording. The piece is arguably a universal. It's a universal with parts that are arranged in a particular structure. It's not enough for a musician to play each constituent note in it in any way she pleases. Only when the notes are played in precisely the right arrangement does it count as Bloch's *Suite*. Were we to compose a piece of music with exactly the same number of the same notes, rests, inflections, and so on, but were to rearrange them in a radically different structure, that piece would fail to be Bloch's *Suite*. Thus, if a piece of music is a universal, it is a structural one, and this structure is crucial to that piece's identity.

David Lewis (1986b) famously rejected structural universals on several grounds. In this essay I defend structural universals against what I regard as the most powerful of Lewis's objections, namely those that raise the charge of logical incoherence. In section 3.2 I discuss the notion of a structural universal beginning with Armstrong's account, and I contrast this with Lewis's own characterization. As will be shown, there are important differences between the two views. Section 3.3 gives an overview of Lewis's critical arguments against structural universals, while section 3.4 presents an overview of some strategies employed in replying to Lewis. Section 3.5 focuses on a recent analysis of the debate by Katherine Hawley (2010), who traces the root of the disagreement to a concern for upholding the mereological principle known as *Composition as Identity*, and section 3.6 shows how rejecting unique composition spells trouble for Humean Supervenience. Section 3.7 reconstructs the most powerful arguments against structural universals, and it shows how those arguments hinge on accepting Humean Supervenience in order to generate their contradictory conclusions. Given that Armstrong's own ontology is one involving *states of affairs* rather than a Lewisian *Humean mosaic*, those objections of Lewis's that at first appear the most devastating, are instead question begging. Although states of affairs are incompatible with Humean Supervenience as Lewis conceived of it, the main incompatibility is with only one part of that thesis, and so there is room for Armstrong to weaken it slightly without abandoning that thesis in its entirety.³⁷

³⁷ A quick note on conventions employed throughout the essay. I will use italicized natural kind terms when I wish to draw attention to the designata of those terms, namely natural kinds, e.g. '*gold*', '*water*', '*penguin*', etc. I will use a similar convention for when I want to draw attention to properties where I will italicize an occurrence of the present participle form of 'be', preceded by an italicized occurrence of a general term, e.g. the property '*being round*', or the property '*being a magpie*'. This distinction is often glossed over in the literature, which accounts for the contrast between my own conventions and passages quoted from the original sources. Occasionally, I will use italics for emphasis and I will also follow the traditional convention of italicizing individual constants, variables, and names of works of art and musical compositions.

3.2 STRUCTURAL UNIVERSALS

Let's begin with a general pass and say that a universal is structural if it's got parts, and further that those parts have a particular arrangement that is in some way important. A more detailed articulation comes from David Armstrong (1978) who offers the following for consideration:

A property, S, is structural if and only if proper parts of particulars having S have some property or properties, T...not identical with S, and this state of affairs is, in part at least, constitutive of S (69).³⁸

Key to Armstrong's view of universals is that they are *immanent*, i.e. universals have no existence apart from their instances, rather than *transcendent*, where universals are said to exist even if there are no particulars that instantiate them. So on the immanence view, the particulars instantiating the structural universal will have constituents that instantiate other universals. To illustrate, suppose we have the one-place universals *being carbon* and *being hydrogen*, and the two-place relation *chemically bonded*. So, a particular object *o* instantiates the structural universal *being methane* just in case it has constituents, *c, h₁, h₂, h₃, h₄* such that *c* instantiates *being carbon*, each *h* instantiates *being hydrogen*, and each pair *<c, h>* bears the relation of *chemically bonded* to one another.

An initial interpretive difficulty lies with understanding what Armstrong means by saying 'this state of affairs is...constitutive of S'. To clarify, he writes

Consider the structural property of *being (just) two electrons*, a property possessed by all two-member collections of electrons. We cannot say that this property involves the same universal, *being an electron*, taken twice over, because a universal is one, not many. We

³⁸ Armstrong notes that a structural universal is a subspecies of *anomoeomerous* property, where a property is anomoeomerous if and only if it is not *homoeomerous*. A property is homoeomerous if and only if for all particulars *x* that have some property *F*, and for all parts *y* of *x*, *y* also has *F* (68).

can only say that the more complex universal involves the notion of two particulars of a certain sort, two instances of the same universal state of affairs (69 – 70).³⁹

So if we have a pair of electrons consisting of particulars e_1 and e_2 , there are (at least) two states of affairs involved: the state of affairs that obtains when e_1 instantiates the property of *being an electron*, and the distinct state of affairs that obtains when e_2 instantiates the same property of *being an electron*. Although each state of affairs involves the property of *being an electron* as a constituent, the states of affairs are distinct since they involve two numerically distinct particulars, e_1 and e_2 . Thus taking a universal “twice over” is to be understood by the notion of distinct states of affairs.

Contrast Armstrong’s account with that given by Lewis (1986a):

In the first place, [a structural universal] is a universal: something that does, or at least can, occur repeatedly. It is instantiated by different particulars, at different spatiotemporal positions...When it is instantiated, it is a nonspatiotemporal part of the particular that instantiates it. In the second place...[a]nything that instantiates it must have proper parts; and there is a necessary connection between the instantiating of the structural universal by the whole and the instantiating of other universals by the parts. Let us say that the structural universal *involves* these other universals... (27).

By Lewis’s characterization, there are two key features to structural universals. First, they are universals, that is, they are entities that can have instances. Presumably all accounts of universals structural or otherwise have this feature in common. Second, “anything that instantiates [a structural universal] must have proper parts”, and moreover, there is some necessary connection between the instantiation of the universal as a whole, and the instantiation of other constituent universals by the constituent parts of the particular. In other words, by

³⁹ The italics are Armstrong’s.

Lewis's characterization, particulars that instantiate a structural universal must be *mereologically complex*; and the proper parts of the particulars involve some variety of *necessity* between the proper parts of the particulars and the universals involved with the structural universal as a whole.

The key differences between the two accounts can now be stated explicitly. Armstrong gives special significance to *states of affairs*, while Lewis emphasizes the mereological *complexity* of particulars and the requisite *necessary* connections these parts involve. Lewis's account makes no mention of states of affairs.

3.3 THREE CONCEPTIONS OF STRUCTURAL UNIVERSALS

Lewis discusses three different conceptions of structural universals: The Linguistic, The Pictorial, and The Magical, and each of these conceptions originates in a chapter from *On the Plurality of Worlds* (reprint 2001) entitled "Paradise on the Cheap". For this essay, however, I will confine my discussion to the conceptions as they appear in "Against Structural Universals" (1986a) (*ASU*).

3.3.1 THE LINGUISTIC CONCEPTION

On the Linguistic Conception, structural universals are set-theoretic constructs built up from other simple universals. By analogy, these universals are constructed much in the same way that a linguistic construction like a sentence is constituted out of more simple linguistic components like words. Although the name "Linguistic Conception" might suggest a non-metaphysical conception, i.e. one that is in some sense purely linguistic, the conception is named so as to draw an analogy between linguistic entities like sentences and structural universals. Structural universals for this conception may be thought of as bearing similarities to predicates.

Thus, satisfying these “predicates” amounts to instantiating the universal. Lewis remarks that he is satisfied with this account’s notion of structure and the necessary connections involved:

We have the required necessary connections between the instantiating of a structural universal by the whole and the instantiating of simpler universals by its parts. And there is no mystery about how these connections can be necessary: they hold by definition. They are just consequences of a semantic recursion which defines satisfaction of complex predicates in terms of satisfaction of the simple ones that are the vocabulary from which the complex predicate is built up; in other words, which defines the instantiation of structural universals in terms of the instantiation of simple universals they involve (32).

The problem with the Linguistic Conception is that it will provide no help for Armstrong since his theory needs to “cover the possibility that there are no simples...” (32). Call this *The Gunk Problem*, in deference to Lewis (1991: 20). A “gunky” world is one in which everything is made of up stuff infinitely divisible into smaller and smaller parts. In other words, a gunky world is one with no *mereological atoms*, that is to say there are parts all the way down. So why does Armstrong’s theory have to cover the possibility that there are no simples? And what sense of “possibility” does Lewis have in mind here? On the one hand we could take “possibility” in the epistemic sense: “For all we know, our world might be a gunky world”. On the other hand we could take “possibility” in a metaphysical sense: “Our world may not be a gunky one, but surely it might have been”. Unfortunately, Lewis says very little else about this objection. Moreover, it’s most likely that Armstrong holds the next conception, what Lewis calls the “Pictorial Conception”.

3.3.2 THE PICTORIAL CONCEPTION

On the pictorial conception, a structural universal is isomorphic to its instances...[A] structural universal is an individual not a set. It is mereologically composite. The

simpler universals it involves are present in it as proper parts. It is nothing over and above them, in the straightforward sense that it is nothing but their mereological sum (33).

If we return to the structural universal of *being methane*, this universal is said to be isomorphic to its instances, much in the way that a ball and spring model of a methane molecule represents the chemical kind methane by being isomorphic.

The trouble with the pictorial conception is to give an account of the structural relations between the constituents. Recall that methane's chemical formula is CH_4 . If we adopt the Pictorial Conception, there is a structural universal, *being methane*, the structure of which is isomorphic to methane instances. This means that the structure of the universal *being methane* must have as constituents *being carbon*, *being hydrogen*, and the relation of *bonding*. However, methane instances have four instances of hydrogen, each of which is bonded to the instance of carbon. So in order for *being methane* to be structurally isomorphic with methane instances, *being hydrogen* needs to occur "four times over", as does the relation of *bonding*. However, the thing that occurs four times over can't be the universal *being hydrogen* since there is only one such universal; neither can it be a particular instance of *being hydrogen*. How can we make sense of this talk of "four times over"? Let's call this *The Number Problem*.

Anticipating several replies from advocates of the Pictorial Conception, Lewis offers four variations of the view and then gives objections to each of the replies.

Variant 1: Drop isomorphism, and hence talk of "many times over", retain the thesis that universals are mereologically composite.

Reply to 1: The structural universals of *being methane* and *being butane* are composed of the simpler universals of *being hydrogen*, *being carbon*, and *bonded*. No isomorphism means *being methane* and *being butane* are the same by the mereological principle the

Uniqueness of Composition, which holds that there are no two objects that have exactly the same parts.

Variation 2: Give an adverbial account of “many times over”. There is only one of universal *being hydrogen*, and the four times over is the way that *being methane* has *being hydrogen* as proper part.

Reply to 2: Consider the kinds *being butane* and *being isobutane*, instances of which contain exactly the same number of instances of *being hydrogen* and *being carbon*. The only difference between them, however, is that these instances have different structural arrangements. However, by the *Uniqueness of Composition* it follows that *being butane* and *being isobutane* are the same kind.⁴⁰ Call this *the Isomer Problem*.

Variation 3: Keep structural universals as having parts, but stipulate a *sui generis* non-mereological form of composition. Reject composition as identity and say each of these combining operations adheres to a principle of uniqueness. Structural universals are built up from simpler universals, but the order in which the simpler universals are combined yields different more complex universals.

Reply to 3: Why are these operations mereological? If these are not mereological, in what sense are the more complex universals composed of the simpler ones?

Variation 4: Come what may: keep the original pictorial conception and face the consequences.

Reply to 4: Suppose we take the talk of “four times over” literally. What are the things that are supposed to occur repeatedly? They can’t be particulars since particulars are spatiotemporally concrete entities. But they can’t be universals since universals are supposed to account for similarity and duplication between particulars – particulars are similar or duplicates because they share the same universal – and duplicate universals

⁴⁰ One might be tempted into thinking that this objection would apply to instances of *being butane* and *being isobutane* too, but this isn’t so. For since the particular instances of the constituents *being hydrogen* and *being carbon* are themselves numerically distinct proper parts of the instances of the structural universals, an instance of *being butane* and *being isobutane* won’t have the exact same parts.

commit one to saying that there are duplicates that don't share universals.⁴¹ Call these non-universal, non-particular things *amphibians*. But now we're left with some absurd questions:

(1) What becomes of our original monadic universals...? Do we have them as well as their amphibians, perhaps instantiated by the same amphibians? (2) Does the same amphibian ever occur as part of two different structural universals? (3) If we have two hydrogen atoms in two different methane molecules, is there indeed a distinction between the case in which they instantiate the same amphibian of the structural universal *methane* and the case in which they instantiate different ones? (40).

Lewis thinks these questions are too absurd to be taken seriously, so a theory that poses them has got to be misguided. Call this *The Absurdity Objection*.

3.3.3 THE MAGICAL CONCEPTION

On the Magical Conception, structural universals have no proper parts, and the term 'simple' is distinguished from the term 'atomic': structural universals are never simple since they always involve other universals, but they are mereologically atomic because they have no proper parts. Since structural universals on the Magical Conception are mereologically simple, talk of 'composition' must be metaphorical; structural universals are therefore only 'composed' of other universals and relations insofar as there is some necessary connection between them. *Being methane* is 'composed' of *being hydrogen* and *being carbon* in that there is a necessary connection between instances of *being methane* and instances of *being hydrogen* and *being*

⁴¹ Of course one might posit a higher-order universal that the two duplicate universals share in common. However, Simons (1982) wonders whether these higher order universals may have duplicates as well, which would require positing a third order universal, and then a fourth, and so on.

carbon. The problem, so reasons Lewis, is that the Magical Conception must explain why there is this necessary connection between the universals:

Why *must* it be that if something instantiates *methane*, then part of it must instantiate *carbon*? According to the linguistic conception, that is built into a recursive specification of what it means to instantiate *methane*. Fair enough. According to the pictorial conception, that is because *carbon* is a part of *methane*, and the whole cannot be wholly present without its part. Fair enough. But on the present conception, this necessary connection is just a brute modal fact (41).

Ultimately, Lewis's objection boils down to a challenge to the proponent of mereologically simple structural universals – give a satisfactory explanation of the required necessities. Call this *The Necessity Challenge*.

To summarize, I have identified five main objections that Lewis deploys against Armstrong's theory of structural universals: First the Gunk Problem, which claims that the Linguistic Conception requires mereological simples, thus cannot accommodate a world in which there are no simples; second the Number Problem against the Pictorial Conception, which requires a specification of how to interpret how one universal can occur "many times over"; third, the Isomer Problem also against the Pictorial Conception, where the distinct universals *being butane* and *being isobutane* threaten the Uniqueness of Composition; fourth, the Absurdity Objection, also against the Pictorial Conception, which claims that a reply to the Number Problem's question of "many times over" taken literally commits one to a bizarre class of entities that are neither universals, nor particulars; fifth, the Necessity Challenge to the Magical Conception, which challenges the advocate of mereologically simple structural universals to explain why it must be the case that particulars instantiating structural universals have parts that instantiate other universals.

I think the two most serious objections are those against the Pictorial Conception, i.e. the Number Problem and the Isomer Problem, for the following reasons. If sound, these arguments would show the account to be logically incoherent. Besides presenting what I take to be the most powerful arguments against Armstrong's view, there are other reasons for focusing these two objections. First, the Gunk Problem is an odd objection since even Lewis notes that it's the Pictorial Conception that Armstrong most likely has in mind. Second, the Absurdity Objection against Variant 4 of the Pictorial account is far too dismissive; after all, an account's causing incredulity is no sure sign of logical incoherence, a point with which Lewis can surely sympathize. Finally, the Necessity Challenge, is exactly that, a challenge, and therefore doesn't charge incoherence. Moreover, it is specifically directed toward the Magical Conception of structural universals. Even though I'll focus on those arguments that charge incoherence of Armstrong's view, it will be useful to discuss some of the ways others have responded to Lewis's criticisms just to orient ourselves within the debate.

3.4 REPLIES

Because there are at least five different objections Lewis gives in *ASU*, there is disagreement among commentators as to which of those is the most serious. There are therefore several strategies that have been employed.

One such broad strategy, as Lewis himself acknowledges, is to "produce a fourth [conception]" (31). Wetzel (2009) gives a conception she dubs "The Occurrence Conception", where she develops the notion of an *occurrence* in terms of mathematical sequences. She uses this fourth conception to reply to several objections, perhaps most prominently what I earlier called the Number Problem. Lewis's mistake, she contends, comes from the assumption that the

constituents of a structural universal like *being methane* are the other universals *being carbon*, *being hydrogen*, and *bonded* instead of *occurrences* of those universals (142 – 150).

Another reply comes from Peter van Inwagen (1986) in the form of a *tu quoque* against similar arguments originating in *Plurality*. The arguments against the Magical Conception, argues van Inwagen, apply equally to set theory, and therefore if the arguments were sound, we would not fully understand set theory, and hence much of mathematics as well. But it is surely false that we don't understand much of mathematics, so Lewis's arguments must go wrong somewhere, though van Inwagen admits he is unable to identify exactly where the mistake occurs (207).

Another strategy involves the rejection of the mereological principle invoked in the Isomer Problem.

Uniqueness of Composition: Two numerically distinct things cannot be composed of exactly the same parts⁴²

Armstrong's (1986) reply to Lewis identifies this as the central bone of contention, as does Katherine Hawley (2010). Essentially the strategy that both Armstrong and Hawley favor is rejecting the formal system of Classical Mereology, a system that admittedly has controversial principles like the Uniqueness of Composition.⁴³ Thus, in rejecting unique composition, both Armstrong and Hawley hold non-classical mereological views of composition. However, they maintain that there is a sense in which something's being 'mereological' just means that

⁴² Varzi (2008) points out that there are several distinct principles invoked in the literature to play this role, and that the principle I state here is in fact not the Uniqueness of Composition, but instead one he calls the Extensionality of Composition. If this causes confusion then please feel free to insert 'EC' in place of 'UC' where relevant.

⁴³ See Appendix A for a very basic overview of CM.

something has parts or constituents, and it is this broader notion of composition they think justifies continuing to use language of parts and wholes.

Hawley's strategy in particular involves reconstructing what she takes to be Lewis's implicit reasoning, and she traces the problem back to another mereological principle known as *Composition as Identity*. Let's call this strategy the *Non-Unique Composition* strategy.⁴⁴ As Hawley (2010) remarks, "there is space for a substantive question about whether there could be a non-composition relation, an intermediate option between taking the relation between correlates and structural universal to be that of unique mereological composition, and taking it to be *sui generis*, and thus, magical" (125). As I will claim later in the essay, it's not Composition as Identity that's carrying the main philosophical weight for Lewis's arguments; the issue goes much deeper to Lewis's views about what is most fundamental. In order to make this claim though, Hawley's reply requires a slightly more detailed examination.

3.5 HAWLEY'S ASSESSEMENT

Hawley claims that the main challenge Lewis raises against all accounts of structural universals is what I earlier called The Necessity Challenge. This was the challenge to provide an account for why it *must* be the case that when an object instantiates *being methane*, a proper part of it also instantiates *being carbon*, and it arose in the context of Lewis's discussion of what he termed, "The Magical Conception", which claimed that structural universals are related to other simpler universals, but not by the relation of parthood. She begins by identifying an ambiguity in Lewis's claims about necessity, and she claims he equivocates between these meanings as he proceeds with his arguments. On the one hand, *being methane* has *being carbon* among its correlates – the term 'correlate' here is Hawley's, which she uses as a neutral term so as not to

⁴⁴ Peter Forrest (1986) also takes this move in his reply to Lewis.

evoke to relation of parthood – at every possible world at which *being methane* exists, and this amounts to claiming that there is a necessary connection between the universals *being methane* and *being carbon*. This relation is one that obtains between two specific universals, *being methane* and *being carbon*, at every world in which the former exists. On the other hand, there is the claim that, “necessarily, if one universal is a correlate of another at a world, then at that very world every instance of the structural universal has a proper part which instantiates the correlate universal” (118-119). This latter claim amounts to saying that there is a necessary connection between the relation of *being-a-correlate-of*, and the relation of “partial *co-instantiation*”. She calls this second claim the ‘co-instantiation principle’.

Suppose then we capture this distinction as follows:

- (a) *Necessarily, being methane has being carbon as a correlate.*
- (b) *Necessarily, if for any world w , a universal α is a correlate of another universal β at w , then at w , all instances of α have a proper part which instantiates β .*

To reiterate, it appears that (a) posits a necessary connection between the specific universals *being methane* and *being carbon*. By contrast, (b) involves not the specific universals *being methane* and *being carbon*, but rather the more general relation of *being-a-correlate-of* and a relationship of partial co-instantiation. Thus, the necessary connections illustrated by (a) and (b) involve *different* universals. Furthermore, not only do the two principles involve different universals, but they also logically come apart:

Even if it is false that *being methane* has *being carbon* amongst its correlates at every world, it may yet be true that in every world where *being methane* does have *being carbon* as a correlate, every instance of the former has an instance of the latter amongst its parts. The two modal claims do not stand and fall together, and it is far from obvious that any explanation of one will explain the other (118-119).

Hawley appears to be making two distinct claims here, one involving the *separability* of these two principles, and another about the *explanatory relationship* they have to one another. The first point is a logical one, which says that the two principles are not equivalent. The second point questions the idea that even if the two principles are not equivalent, they may provide explanatory support for one another. According to her, it's not clear that the truth of one would serve to explain the truth of the other.

More specifically the first claim is that, even if (a) is false, (b) might still be true for all worlds in which it's true that *being methane* has *being carbon* among its correlates. To illustrate, she offers two arguments involving purportedly analogous principles, one from the realm of material particulars, the other from Armstrong's theory about the laws of nature. Let *m* be a constant that picks out the individual with whom I am identical, and let *c* be a constant that picks out a particular cell of my body that is a part of me.

(a') *Necessarily, m has c as a part*

(a') follows from a mereological thesis known as *mereological essentialism*, which says that a whole's parts are essential to it. By contrast, consider the following principle, where *a* and *b* are material particulars:

(b') *Necessarily, if a is part of b, then a occupies a sub-region of the region occupied by b*
(119).

Hawley calls (b') the *sub-region principle*, which posits a necessary connection between the relation of *being-a-part-of* and the relation *occupying-a-sub-region-of-the-region-occupied-by*.

It is generally held that mereological essentialism is false since intuitively objects can persist despite the loss of a few of their parts; likewise (a') also seems false since it is presumed that I can survive the loss of one (and indeed many) of my cells. Thus, it is generally accepted that

there are no necessary connections between particular parts and the particular wholes of which they are parts. However, at least for the realm of material particulars, (b') is true, for it seems false that it's possible for a part of a whole to not occupy a sub-region of space occupied by the whole. Next, Hawley offers two more analogous necessity claims from Armstrong (1983) involving the second-order relation of *N*, which relates first-order universals to form laws of nature. If the property of *being F* and the property of *being G* are related to one another by Armstrong's higher order *N*(ecessitation) relation at some world, then at that world, it's true that All Fs are Gs. However, "Armstrong argues that there is a necessary connection between the *N* relation and a certain co-instantiation relation [the analogue to (b)], but denies that the *N* relation holds of necessity where it holds at all [i.e. the denial of the analogue to (a)]" (119).

The second claim Hawley makes from the above passage involves a claim about the principles and their explanatory relationship to one another, meaning that it's not clear that the theoretical explanation for the truth of either (a) or (b) (and evidently so too with (a') and (b'), and their unstated Armstrongian analogues) would serve to explain the truth of the other(s). This is especially relevant for Lewis's objection since the Necessity Challenge is precisely a request for an explanation of the necessities of structural universals. So if Hawley is right in distinguishing the necessities involved in (a), (b), and their respective analogues, Lewis's challenge should be separated into two distinct questions. First, what explains the necessity in (a) (and its respective analogues)? Second, what explains the necessity in (b) (and its respective analogues)?

The key move Hawley takes is to argue for a fourth conception, one that occupies the conceptual space between the Pictorial and Magical conceptions. The strategy is to retain portions of the Pictorial Conception, but to deny the commitment to Classical Mereological

principles responsible for generating some of Lewis's more powerful objections. This would allow Armstrong and Hawley to retain talk of parthood and composition, but not commit to the Magical Conception. What this ultimately involves is arguing for the legitimacy of *non-unique composition*. As both Armstrong (1986) and Forrest (1986b) observe, if there are states of affairs, then they involve non-unique composition, while Lewis's (1986b) reply is that this gives us evidence against states of affairs. So why does Lewis think unique composition is so important? Evidently, it's because he thinks non-unique composition is "unintelligible" (Lewis 1986a), but then we're still left with the question of why this is so. According to Hawley, the reason has to do with another mereological principle Lewis holds dear, namely Composition as Identity, which in its strongest form is the view that the composition relation – i.e. the relation an object's parts bear to the whole – just is the relation of identity. More specifically, Lewis thinks that the composition relation is only *analogous* to identity, though it is not strictly speaking the same.⁴⁵ Let's call this weaker version, *Composition is Analogous to Identity* (or CAI for short).

What follows next is Hawley's interpretation of Lewis's implicit reasoning that connects CAI, with Unique Composition, and I'll call the advocate of this position *Hawley's Lewis*. Hawley's Lewis desires to uphold the Uniqueness of Composition, first, because (in Hawley's words), "uniqueness is supposedly a prerequisite for drawing a close analogy between composition and identity" (126), and second, because CAI can be used to explain the necessities from (a), (b), and their respective analogues. The first argument is intended to show why CAI can explain the necessity of the sub-region principle, or (b') from above:

The analogy [Composition as Analogous to Identity] can explain central features of the composition relation. If *a* and *b* are material particulars then, necessarily, if *a* is a part of *b*, then *a* occupies a sub-region of the region occupied by *b*. This sub-region principle

⁴⁵ See Sider (2007) for more on this.

expresses a necessary connection between the parthood relation and another relation. Compare this to Leibniz's Law: necessarily, if *a* is identical to *b*, then *a* instantiates all and only the properties that *b* instantiates. Leibniz's Law expresses a necessary connection between the identity relation and the indiscernibility relation. Moreover it is an acceptably brute necessity, if anything is, and so taking composition to be analogous to identity helps render the necessity of the sub-region principle acceptable (either brute but acceptably so, or else reducible to the acceptably brute necessity of Leibniz's Law) (126).

There seem to be two claims being made here, one that relies on drawing an analogy between the sub-region principle and Leibniz's Law, where the needed link to draw the analogy comes from CAI, and then a stronger argument about the sub-region principle's being 'reducible' to Leibniz's Law. I'll refer to the arguments from this passage as HL1 below. The next passage containing Hawley's argument is as follows:

...taking the relation between correlates and structural universal to be analogous to identity would render the necessity of the co-instantiation principle respectable. 'Why *must* it be that if something instantiates methane, then part of it must instantiate carbon?' [citing Lewis 1986a: 41] Mystery! But compare the following: why *must* it be that if something instantiates *being carbon*, then it must (sic) [sic] instantiate *being carbon*? No mystery here: *being carbon* is identical with *being carbon*, so of course the former is instantiated whenever the latter is. Similarly, if *being carbon* is a part of *being methane*, and parthood is analogous to identity, then the fact that *being carbon* is instantiated wherever *being methane* is no longer looks like an unacceptable brute modality (126).

So, Hawley's Lewis thinks that CAI can explain both the necessity of the co-instantiation principle (b), but also the necessity of (a) as well. I'll call the reasoning from this passage HL2. What is clear from these passages is that Hawley's Lewis expects the analogy between the relationship of composition and the identity relation to do some pretty serious explanatory work.

Hawley's next move is to argue against the reasoning just attributed to Lewis. She does this by maintaining that deniers of unique composition can also rely on the analogy between composition and identity to account for the necessity of (a) and (b). Deniers of unique composition just have to weaken the analogy between composition and identity a little bit more, which is to say that although it's claimed that composition and identity are still analogous, they no longer share the feature of both being unique. Doing so would supposedly allow proponents of non-unique composition to account for the necessity of the co-instantiation principle by licensing talk of "parthood", without thereby being committed to magic.

So, in sum, Hawley argues that Lewis's concern with upholding unique composition comes from the need to first, preserve an intelligible notion of composition, and then second, to account for the necessity of (a) and (b). If composition is non-unique, then it's not sufficiently analogous to identity for it to account for the necessity of the co-instantiation principle, and Hawley then argues that this reasoning fails since there seems to be no good reason not to weaken the analogy between composition and identity just a little bit more.

I want to preface the following critical remarks by stating that I think Hawley is on the right track in rejecting certain principles from Classical Mereology, and I also think that tracing the difficulty to the principle of Composition as Identity is an important step in getting to the root of the disagreement. However, in my view Hawley stops just short of the main issue, which I think leads back to central issues of fundamentality. Stopping at Composition as Identity leaves us with several puzzling questions, and there are three main critical points I want to raise about Hawley's interpretation.

First, considering the reasoning employed by Hawley's Lewis. The explanatory arguments seem a little weak and the reasoning employed is somewhat unclear. Consider the

first argument, HL1. The first observation to note is that the first claim appears to be an argument from analogy, which draws a comparison between the sub-region principle and Leibniz's Law. If composition *were* just identity, in a strong sense, drawing a comparison between the two would at least initially seem warranted. But as it stands, the claim seems contentious at best. The second claim appearing in the parenthetical about the sub-region principle's reducibility to Leibniz's Law is even less clear. On the one hand, the passage might mean that the sub-Region principle can be reduced to Leibniz's Law without the assumption of CAI or something like it. On the other hand, the passage might mean that the reduction can be achieved if one assumes CAI or something similar to it. Even so, neither of these options pans out. To see these difficulties it may be useful to have a side-by-side comparison of the principles Hawley has in mind:

Sub-Region Principle: Necessarily, if a is a part of b , then a occupies a sub-region of the region occupied by b .

Leibniz's Law: Necessarily, if a is identical to b , then a instantiates all and only the properties that b instantiates.⁴⁶

Suppose we try to first option, which is to reduce the Sub-Region Principle to Leibniz's Law without use of CAI. The terms in need of reduction are, "part", and "occupies a sub-region of the region occupied by", and these must then be cashed in terms of the identity predicate, and other properties/relations. It's unclear how a reduction of the parthood relation is supposed to proceed, and it's even less clear for the relation of *occupying a sub-region of the region occupied by*. The second option, reducing the principle by appealing to something like CAI, is even worse

⁴⁶ This is a minor point, but I'm a little uneasy about calling this "Leibniz's Law" since it's formulated with individual constants instead of variables and thus fails to capture the general applicability of the Law that's captured by other formulations. Compare: Necessarily, if $x = y$, then what's true of x is true of y and what's true of y is true of x .

off. The claim that *composition* is analogous with identity is not the claim that *parthood* is analogous with identity. And although Lewis himself might have endorsed the view that all mereological relations are in some way analogous to identity, that claim is incompatible with Leibniz's Law.⁴⁷ To see why, let's consider the *proper-parthood* relation, and consider the fact that a rectangular brick can be a proper part of a circular bit of architecture. A whole's parts can have a property the whole lacks, while a whole can have properties the parts lack. This feature seems to come out of the *asymmetric* nature of the proper-parthood relation. When something's a proper part of another thing, it's not the case that the other thing is a proper part of the first thing. Identity, by contrast is a *symmetric* relation. Thus, the Sub-Region Principle, the claim that all mereological relations are analogous to identity, and Leibniz's Law are incompatible.

Suppose that the proponent of this interpretation replies that what's important to bear in mind for the principle of Composition as Identity is that the relation of composition is what holds between *the class of things* composing a whole when they are taken *collectively*, and the whole to which it is identical.⁴⁸ However, as Hawley herself cites, Sider (2007) notes that the difficulty with the strong identity claim between composition and identity is the collapse of the singular/plural distinction. Suppose we let this slight difficulty slide. What Hawley might mean is that *a* is the mereological sum identical with the individual *b*, but then the word "part" as it occurs in the sub-region principle is *improper parthood* – *a* is either a proper part *or* is identical with *b* – rather than *proper parthood*. This claim is compatible with idea of reducibility. The problem with this move, however, is suggested by the name of the Sub-Region Principle itself.

⁴⁷ See Lewis (1991: 84-85) for his discussion of why mereological relations are analogous with identity.

⁴⁸ See Wallace (2011) for a nice overview of the Composition as Identity thesis. Wallace defends a version of Composition as Identity against several objections, many of which stem from Leibniz's Law. What becomes evident from this literature is that the main issue is to argue that Composition as Identity and Leibniz's Law are *compatible*.

We need to account for the necessity of a *proper*-part that occupies only a *sub*-region of the whole, not the region of space occupied by the whole itself. Thus the prospects for reducibility look bleak.

The second set of reasons against Hawley's interpretation is against the importance she devotes to the Necessity Challenge. This criticism comes from the observation that the Necessity Challenge arose specifically as an objection against the Magical Conception, and what was characteristic about that conception was that the structural universals were *mereologically atomic*, that is to say, they had no constituents. If it's maintained that structural universals have no constituents, then it's understandable to want to know why certain correlates are involved with the universals they're involved with. But if it's maintained, as Armstrong does, that it's still constitution relating a structural universal and its correlates, then the battle shifts to another entirely topic concerning whether a particular formal system, i.e. mereology, is the only system adequate to capture the relationships between parts and wholes. This discussion is now no longer about necessity, but rather the legitimacy of a particular formal system.

The third reason for thinking we need to go beyond Composition as Identity to account for Lewis's concern for upholding unique composition is that drawing a comparison between identity and composition does not fully explain why Lewis thought non-unique composition was "unintelligible". Non-unique composition is explanatorily unhelpful for accounting for the necessity of the sub-region and co-instantiation principles, and so drawing a comparison between composition and identity would play no useful theoretical role. But even as Hawley herself points out, proponents of non-unique composition can still draw on the analogy between composition and identity, albeit in a weaker form. Rendering something explanatorily unnecessary does not thereby make it unintelligible. So if we are to take Lewis as his word in

thinking that non-unique composition is unintelligible, Hawley's explanation gives us no answer for why this is so.

In this section I outlined Katherine Hawley's assessment of the debate between Lewis's arguments against structural universals. Her strategy was to address what I earlier called Lewis's Necessity Challenge, which asks for an account of the necessary connections involved between structural universals and their correlates. She did this by arguing for a non-unique form composition. Her argument relied on reconstructing what she deemed was Lewis's implicit reasoning behind thinking that composition must be unique, which she traced to his concern for upholding an analogy between composition and identity. She then argued that the explanatory power of the analogy is open to those who reject unique composition. I objected to this reasoning on the grounds that the arguments she attributes to Lewis are a little weak and somewhat unclear, that the Necessity Challenge was directed specifically at the Magical Conception of structural universals, and that even if her reconstruction of Lewis's reasoning is right, it wouldn't fully explain the unintelligibility of non-unique composition.

In my view, the explanation for why Lewis thinks non-unique composition is unintelligible goes far deeper than Composition as Identity, and it's one that Hawley herself mentions, though only in passing.⁴⁹ The reason is because it spells trouble for *Humean Supervenience*. If Humean Supervenience is true, how could composition be non-unique? This picture I submit, does sound unintelligible. In the next section I show how denying Uniqueness of Composition requires rejecting Humean Supervenience.

⁴⁹ For instance, "To reject the uniqueness of composition is to accept that sortal properties of composite objects cannot be reduced to the intrinsic properties of and spatiotemporal relations between their parts" (127).

3.6 HUMEAN SUPERVENIENCE AND UNIQUE COMPOSITION

In the *Introduction* to the second volume of his collected papers, Lewis (1986c) gives a general characterization of his thesis:

Humean Supervenience is named in honor of the greater denier of necessary connections. It is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another...We have a geometry: a system of external relations of spatiotemporal distance between points. Maybe points of spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that (ix-x).

According to Humean Supervenience (HS), the world consists of one-dimensional objects, points or point-like things, and these things, whatever they may be, instantiate fundamental natural properties. In addition, there are also spatiotemporal relations that obtain between these point-sized things. So according to this picture, there are points, and spatiotemporal relations between them, and that's it. Everything else, all other facts involving things "bigger" than these point-sized things, supervenes on the properties instantiated by the points and the spatiotemporal relations between them. In later work, Lewis (1994) clarifies the original statement of the thesis in response to criticisms from Haslanger (1994). Based on those later remarks, some commentators distinguish between several parts to the Humean thesis. Weatherson (forthcoming) for instance says that HS can be thought of as the conjunction of three separate theses:

Truth supervenes on being (Bigelow, 1988)... all the facts about a world supervene on facts about which individuals instantiate which fundamental properties and relations.

Anti-haecceitism. All the facts about a world supervene on the distribution of qualitative properties and relations; rearranging which properties hang on which ‘hooks’ doesn’t change any facts.

Spatio-temporalism. The only fundamental relations that are actually instantiated are spatio-temporal, and all fundamental properties are properties of points or point-sized occupants of points (1).⁵⁰

The first thesis is one that ensures that the list of all facts about a world is exhaustive. The idea is that whatever facts there are, this list of facts can be entirely accounted for in terms of lower level facts about what exists at the fundamental level, that is in terms of the facts about which individuals instantiate the most fundamental natural properties and relations. In slogan form, and as the name of the thesis suggest, “Truth supervenes on being”. The second thesis rules out the possibility of *haecceitistic* worlds in which facts about individuals fail to supervene on the distribution of qualitative properties and is related to Lewis’s *counterpart theory*. To illustrate, Weatherston considers a scenario ruled out by Anti-haecceitism. This would involve two distinct worlds “with the same distribution of qualitative properties, but with different facts obtaining in each” (1). A haecceitistic world would be one in which David Lewis and David Armstrong swapped qualitative places, where Lewis is the Australian philosopher who authored *A World of States of Affairs* and lived until 2014, and Armstrong was the author of *On the Plurality of Worlds*, but died in 2001. But in this world there is nothing qualitative that would make the Australian-born philosopher a counterpart of *Lewis*. Finally, and most importantly for my purposes, the third thesis spells out Lewis’s view of fundamentality, i.e. what exists at the most

⁵⁰ The Bigelow citation in the first thesis is Weatherston’s own. Page references to the Weatherston paper are to the electronic copy available at the following address: <http://brian.weatherston.org/HumeanSupervenience.pdf>

fundamental ontological level. The only fundamental relations are spatiotemporal, and there are no fundamental properties other than those instantiated by point-sized objects.

The theoretical upshot to upholding this thesis should be evident. For one thing, the austerity of the view certainly has a principle of parsimony on its side. Spatio-temporalism rules out any relations besides spatio-temporal ones, and it rules out the existence of “fundamental properties of [spatially] extended objects” (Weatherson, 2). This means we can avoid proliferating other sorts of entities beyond theoretical necessity, since everything supervenes on what’s going on at the fundamental level. For another, the thesis is remarkably ambitious. If right, it gives us a completed picture of the world. If all we need to get a complete list of all facts about the world is the stock of fundamental ontological entities given by Spatio-temporalism, then that would be an extremely powerful theory indeed. In what follows, I shall proceed assuming that these three theses capture the intended principles articulated in Lewis’s informal remarks. Notice that in saying that HS involves the conjunction of each of these, a rejection of any one is sufficient for the denial of HS.

That denying Uniqueness of Composition (UC) potentially spells trouble for Humean Supervenience (HS) may be suspected by those already familiar with the puzzles of material constitution, and the difficulties associated with upholding the view that two numerically distinct objects can occupy the same spatiotemporal location. My argument will show that if numerically distinct spatiotemporally coincident objects are problematic for Humean Supervenience, then the structural universals of *being butane* and *being isobutane* are as well, since these structural universals are analogous to those cases.⁵¹

⁵¹ One reason for focusing on the case of supposed spatiotemporal coincidence is that we can avoid taking a stance on the topic of temporal parts in formulating the principle of Unrestricted Composition. What I mean is that the *endurance* theorist – who denies that there are temporal

Some material objects are said to *coincide*. To take one familiar example from Allan Gibbard (1975), let “Goliath” name a particular statue and let “Lumpl” name the lump of clay out of which the statue is constituted. To avoid the ready solution proposed by Lewis (1976) when Lumpl and Goliath exist at different times, one version of the story has it that Lumpl and Goliath come into existence at precisely the same time, and are then subsequently destroyed simultaneously as well. Those who believe in spatiotemporal coincidence say that Lumpl and Goliath are distinct since they have different modal properties since it’s possible that Lumpl survives being squashed, while Goliath cannot. Thus by Leibniz’s Law, Goliath and Lumpl are distinct. Notice that this example is one that involves an apparent violation of Uniqueness of Composition: if sound, the argument concludes that Goliath and Lumpl are numerically distinct objects despite sharing exactly the same parts.⁵² If we accept that there are in fact two numerically distinct material objects that share all of their proper parts, then that means those two objects must occupy the same spatiotemporal location. But according to HS, all facts about a world must supervene on the distribution of qualitative properties and relations. (i.e. Truth Supervenes on being and Anti-haecceitism). Thus the distinctness of Lumpl and Goliath must supervene on a qualitative or relational difference. However, for spatiotemporally coincident objects, there is no difference in parts, and there is no difference in spatiotemporal arrangement of those parts, since they have all parts in common, so there’s no difference in the distribution of qualitative properties and relations. Thus, it follows from the view that no difference in parts and

parts – will claim that UC is false without appending a temporal qualifier, e.g. “No two things can have all the same parts *at the same time*”. In order to be as charitable as possible to Lewis’s own position, we’ll make a concession to the *perdurantist* advocate – the believer of the existence of temporal parts – and focus on coincident objects since in this case a difference in temporal parts can’t make the difference. Thus we can retain UC in its strongest and unqualified form.

⁵² Lewis’s (1971) reply to the argument attacks the use of Leibniz’s Law in contexts with occurrences of the word “I”, claiming that these contexts are referentially opaque. For discussion of the move to restrict Leibniz’s Law from certain contexts see Koslicki (2005).

no difference in spatiotemporal arrangement of those parts, that Humean Supervenience is false.⁵³

Recall now the structural universals from the Isomer Problem, *being butane* and *being isobutane*. Lewis maintained that those universals were counterexamples for unique composition since they are distinct universals yet share all of the same parts. Thus, according to Lewis, the structural universals of the isomers *being butane* and *being isobutane* are analogous to cases involving spatiotemporally coincident material objects. They are analogous in that the distinctness of *being butane* and *being isobutane* supervenes neither on a difference in their parts, nor on a difference in the spatiotemporal arrangement of those parts. The parts of a structural universal cannot differ with respect to the distribution of their qualitative properties and spatiotemporal relations. If this reasoning is right, then structural universals are analogous to the cases with material spatiotemporally coincident objects, and both result in the falsity of Humean Supervenience.

If we accept that this is right, then showing that non-unique composition is incompatible with Humean Supervenience has a further benefit. We can now make sense of Lewis's remarks about non-unique composition being unintelligible. If all facts about a world supervene on Lewis's Humean mosaic, how would it be possible for composition to be non-unique? Indeed, if Humean Supervenience is true, non-unique composition is utterly unintelligible since it entails the falsity of the former thesis. In other words, HS and non-unique composition are

⁵³ Weatherson (forthcoming) remarks that it is sometimes difficult to formulate Humean Supervenience straightforwardly as a supervenience thesis (2-3). The difficulty with doing this is that several theses of supervenience have been distinguished, among them strong and weak forms of *local supervenience*, and strong and weak forms of *global supervenience*. Sider (1999) points out that some forms of global supervenience are compatible with material coincidence, but later changes his mind (2008). Instead of reformulating Lewis's thesis into one primarily about supervenience, I think it's best to stay close to the original formulation.

incompatible. We now have the missing piece to account for Lewis's aversion to those cases supposedly violating uniqueness. And now that we've shown the connection between Humean Supervenience and unique composition, the reasoning behind the most powerful of Lewis's objections against structural universals becomes clearer.

3.7 LEWIS'S OBJECTIONS REVISITED

As I mentioned from the outset of this essay, my defense of structural universals is against the strongest of Lewis's arguments, namely those that charge unintelligibility. Thus, the makings of two *reductio*-like arguments can be found in Lewis's objections, particularly against what he called The Pictorial Conception. Recall that one main challenge for that view was to give a satisfactory account of how a universal like *being hydrogen* or *bonded* can occur many times over as constituents of a structural universal like *being methane*. A related problem involves the isomeric universals *being butane* and *being isobutane*, which according to Lewis, are composed of exactly the same parts.

The first argument corresponds to what I have above called the Number Problem, and we'll call it Reductio L1. Assume for *reductio* that *being methane* is a structural universal. If *being methane* is a structural universal, *being hydrogen* and *being bonded* must occur four times over. Moreover, the thing that occurs four times over must be either (i) a universal or (ii) a particular. Since whatever occurs four times over is neither a universal – because there's only one universal *being hydrogen* and only one universal *bonded* – nor a particular – because we're talking about the universal, not particulars – it must not be the case that *being methane* is a structural universal.⁵⁴ But why accept that the something occurring four times over must either be a universal or a particular? Furthermore, why accept that whatever occurs four times over is

⁵⁴ See Bennett (2013) who embraces the objection by sketching a mereological system that allows an object to have one and the same part multiple times over.

neither of these? The reason for accepting these premises comes from the third conjunct of Humean Supervenience, the claim about fundamentality called Spatio-temporalism. Consider the fact that that thesis tells us that the only fundamental relations that exist are spatiotemporal ones, and that the only fundamental properties are those instantiated by points or point-like objects. In other words, Lewis's view of fundamentality allows for universals (properties), particulars (points), and spatiotemporal relations. If the idea of occurring many times over cannot be cashed in these terms, then what else is there to do the work? If one goes on to insist that we take talk of occurring four times literally, and that it can't be articulated in Humean terms, then Lewis's argument collapses to what I earlier called the Absurdity Objection, which dismissed these 'amphibians' as being too absurd to take seriously.

The second argument is a reconstruction of what I earlier called The Isomer Problem and we'll call it Reductio L2. Assume for reductio that *being butane* and *being isobutane* are structural universals, and let's stipulate that *being butane* and *being isobutane* are numerically distinct. The only constituents of the structural universals *being butane* and *being isobutane* are *being hydrogen*, *being carbon*, and *bonded*. Thus, *being butane* and *being isobutane* share the exact same parts. Since Humean Supervenience is true, composition must be unique, which means that *being butane* and *being isobutane* are identical. Therefore, *being butane* and *being isobutane* are not structural universals.

What should now be clear is that in order to generate the *reductio*-like arguments, each argument requires an assumption whose justification depends on a substantive picture of ontology provided in the form of Lewis's thesis of Humean Supervenience. In Reductio L1, those premises were those requiring that the language of occurring *four times over* must be construed in terms of universals, particulars, or spatiotemporal relations. Indeed, the key thought

behind the objection lies with the apparent absurdity in trying to articulate how it can be that certain non-trivial structural relations obtain between one and the same universal. What's more the premise from Reductio L2 in need of Humean Supervenience was the Uniqueness of Composition, which was the key premise used to reduce the view to absurdity.

In highlighting the reliance on Humean Supervenience in the above arguments, I don't wish to claim this is the only way to escape the objections, as there are several other paths one may be inclined to take. The point to draw from this is that Humean Supervenience plays a substantial role in the arguments, and this is something not made explicit in the debate with Armstrong. I also wish to point out that the thesis causing the most trouble is the one about Spatio-temporalism. This is especially important given that Lewis devotes special attention to Armstrong's theory in particular, even though the arguments are intended to have wider applicability to those of Forrest and Bigelow and Pargetter. The problem, however, with focusing on Armstrong's theory can be seen if we return to his original characterization of structural universals from 1978.

A property, S, is structural if and only if proper parts of particulars having S have some property or properties, T...not identical with S, and this *state of affairs* is, in part at least, constitutive of S (69).⁵⁵

Recall that in Section two I pointed out the main differences between Armstrong's characterization and Lewis's, and I called special attention to the fact that Armstrong defines his notion of a structural universal explicitly in terms of states of affairs. Moreover, for Armstrong a state of affairs just is "a particular's having a certain property, or two or more particulars standing in a certain relation" (80), and he regards them as the fundamental constituents of the world. States of affairs in this respect have no independent existence from one another. It's this

⁵⁵ Emphasis added.

that characterizes Armstrong's *immanent* realism from the *transcendent* version of realism. Moreover, states of affairs are more than just their parts. Armstrong (1986) remarks on this very issue in his reply to Lewis's criticisms:

Let *a* and *b* be two particulars, and R be a non-symmetrical relation. Let it be the case that *a* has R to *b*, and that *b* has R to *a*. We have two distinct states of affairs ('two different things'), yet, in a clear sense of the word 'composed', they are composed of exactly the same parts: *a,b* and R (85).

In this respect Armstrong's picture of fundamentality is much different from Lewis's Humean mosaic, in that the former includes states of affairs while the latter picture does not. More explicitly, Armstrong can be seen as either denying or weakening the third thesis to HS, namely Spatio-temporalism. Since Armstrong defines structural universals explicitly in terms of states of affairs, and since the most serious of Lewis's objections to them relies on the implicit use of Humean Supervenience – to wit, a picture of fundamentality without states of affairs – it would appear that Lewis's criticisms against Armstrong's theory are question-begging. Even Armstrong himself suspects this when he asks, "...is not Lewis close to begging the question against me?" (85). If what I've said here is on the right track, then Armstrong's suspicion, even though it goes no further than the rejection of compositional uniqueness, turns out to be warranted after all.

Although Lewis's appear to beg the question against Armstrong, the problematic part of HS was the claim about what exists at the most fundamental level, i.e. the thesis of Spatio-temporalism. Although Armstrong's ontology is incompatible with this thesis, it is arguable that his picture of fundamentality is consistent with the other parts of HS involving supervenience. Where the two theories disagree is what is included in the base – states of affairs or not. The

proponent of structural universals needn't reject HS wholesale, but can weaken it slightly by allowing a slightly less austere ontology without abandoning the claims about supervenience.

3.8 CONCLUSION

Before concluding I'd like to respond to the potential *tu quoque* objection that at least one of my criticisms of Hawley applies to my own criticisms of Lewis. What I've done is to give a reconstruction of what I take to be Lewis's implicit reasoning for his arguments against the Pictorial Conception, only to accuse him of begging the question against Armstrong. Aren't my criticisms of Hawley akin to the pot that chides the kettle for being black? This claim has some air of truth to it, but as I pointed out in the discussion of Hawley, I think the account I give does better at explaining why Lewis is concerned about non-unique composition. Although Composition as Identity is important for Lewis's theory, presumably its importance stems from the desire to maintain as austere an ontology as possible, and this comes from the deeper, more fundamental thesis of Humean Supervenience.

I have argued that what I think are the most powerful of Lewis's arguments against Armstrong's structural universals require the presupposition of Humean Supervenience, and I have argued that this is a question-begging move. This was so because of Armstrong's original definition of a structural universal, which explicitly uses states of affairs. Since the mereological principle of the Uniqueness of Composition was used to criticize Armstrong's structural universals, and since that principle requires Humean Supervenience, Lewis's criticisms require the presupposition of the falsity of Armstrong's view.

I would however be remiss if I were to conclude without acknowledging the following fact. If my arguments are sound, then this absolves Armstrong's structural universals from the charge of incoherence (at least as far as the Number and Isomer problems are concerned),

although what is now required is that the notion of a state of affairs does some serious theoretical work. What Lewis thought were utter refutations may now be reformulated as challenges, that is, requests (perhaps pressing ones) for a fuller description of how states of affairs are to carry the philosophical weight they've been assigned. Can we give an account of the language of 'many times over' by making use of a state of affairs? Can states of affairs give a satisfactory account of the structures of isomeric properties from chemistry? Can they account for certain necessary connections? But a theory with pressing lingering questions is better than one that's dead in the water.

Essay 3

4. CAUSAL STRUCTURE AND THE ISOMER PROBLEM

4.1 INTRODUCTION

In the previous essay I gave a defense of the very idea of structural properties against objections from David Lewis. The conclusion to draw from that essay was that the idea of a structural property is not, as Lewis would have it, conceptually incoherent. But this still leaves open the question of what this structure involves, and more importantly, how structure plays a role in telling us what natural kinds are. This essay gives a basic overview of how one can talk about natural kinds as being complex causally structured properties.

Some like Bird (2007), and Hawley and Bird (2011) have suggested that kinds can be formulated in terms of complex properties.⁵⁶ By “complex”, they have in mind something like the following idea: complex properties are somehow built up from or constructed out of other simpler properties. The theoretical appeal of such an account for a theory of fundamental ontology is evident: if successful, this proposal would obviate the need for a *sui generis* category of kinds within a fundamental theory of ontology. For instance E.J. Lowe (2006) has what he calls a “four-category ontology” where *kinds* are a fundamental *sui generis* category separate from and not reducible to the other categories of *attribute*, *object*, and *mode*. However, it’s possible to give a theory of kinds without having to posit a separate fundamental category, a principle of parsimony will favor that theory.

Hawley and Bird’s suggestion shares close affinities with David Armstrong’s (1978) theory of structural universals, and I shall use his theory as a starting point to orient the following discussion. To begin, we need to be a little more precise about what we mean by calling a

⁵⁶ Tobin (2013) also argues for the claim that a *sui generis* category of *kind* is unnecessary.

property a “complex property”. To illustrate, consider the property of *being blue and spherical*, which is instantiated by those objects which simultaneously instantiate the property of *being blue* and the property of *being spherical*. What is the relationship between these properties? A natural place to start might be to say that the simpler properties of *being blue* and *being spherical* are components of the complex structural property *being blue and spherical*, and because whenever the two simpler properties occur conjointly in a particular, that particular satisfies the conditions for instantiating the more complex property. Call this a *conjunctive property*.

But not all complex properties are as easy to explain. Consider the chemical compound methane (whose molecular formula is CH_4), and the complex property *being methane*. If we were to proceed in giving an account similar to the one just described for the conjunctive property *being blue and spherical*, we can see that there is a crucial difference between the two. There are four hydrogen atoms in methane molecules, and hence, the property of *being hydrogen* must in some way occur four times in the complex property of *being methane*.⁵⁷ What this example shows is the need for a more sophisticated account beyond that of mere conjunction.

In this essay I want to explore the idea that *causal structure* is important for the characterization of natural kinds as complex properties. To motivate the idea that causal structure is particularly important for natural kinds, I focus on certain cases from chemistry since chemical kinds are sometimes thought to be paradigmatic examples of precisely defined natural kinds. To accomplish this task, I will examine an alternative view I’ll call the *simple constitutive* account for chemical kinds. “Structure” for this account I’ll argue, is construed far too restrictively. I’ll show how the simple constitutive view has difficulties accounting for more complex chemical kinds, and I will focus on the problems posed by isomers. The simple

⁵⁷ See Lewis (1986) for an objection about the idea of occurring many times over. See Bennett (2013) for a reply to this objection.

constitutive account errs in two ways: first, it holds the mistaken principle that sameness of molecular formula is sufficient for sameness of parts. The constituents of more complex properties are, as their name suggests, far more complex than the simple constitutive account suggests. Second, the simple constitutive account fails to recognize the important causal differences between complex properties, and how these causal differences are tied closely to the structural complexity of chemical kinds. I'll then discuss the notion of causal structure itself by framing the question in terms of Sydney Shoemaker's (1980) causal theory of properties.

4.2 The Simple Constitutive Account

Let's say that a theory of complex properties is a *constitutive* account if the theory is cashed in the language of parts and wholes. According to this account a complex property like *being methane* is a complex whole with other simpler properties as parts or constituents. Those constituents include *being hydrogen*, *being carbon*, and then presumably the two-place relation *bonded*. There are several places where talk of the constituents of chemical kinds pops up in the literature, for instance, in discussions from the philosophy of chemistry regarding the thesis known as *microstructuralism*.⁵⁸ Another place where this topic takes center stage comes from one of the more famous debates within metaphysics between David Lewis (1986), who criticizes the constitutive account of complex properties proposed by David Armstrong's (1986) theory of structural universals.⁵⁹ Lewis attributes to Armstrong not just a *constitutive* account, but rather, what I'll call the *simple constitutive* account. The simple constitutive account holds that the only proper parts of a complex chemical property like *being methane* can be read off from the kind's chemical or molecular formula. By this account the exhaustive list of proper parts of the complex property of *being methane* comprises the properties *being carbon*, *being hydrogen* (in a

⁵⁸ See for example Hendry (2006), and Tobin (2010).

⁵⁹ I argued in the previous chapter that this was a mistaken attribution on Lewis's part.

ratio of one to four respectively), and the relation of *bonded*. This account is then applied to other more complex chemical kinds.

Why would anyone hold this simple account? One upshot to holding a simple constitutive approach I hinted at in the earlier discussion of conjunctive properties. If the properties of *being carbon*, *being hydrogen*, and *chemically bonded* are quite literally constituents of the complex property *being methane*, this would explain why instances of *being methane* must have proper parts that instantiate the other properties, for the simple reason that a whole cannot be wholly present without its parts.⁶⁰ Another advantage comes from its theoretical simplicity: if a mereological theory can accommodate various phenomena without the need for *sui generis* entities and relations, then that's clearly a theoretical advantage. Furthermore, constitutive accounts appear to work for a large number of paradigmatic cases typically cited in the philosophical literature. The complex property of *being gold* may be cashed in terms of *having the atomic number 79* (among others), which is subsequently construed in terms of the number of protons in the nucleus of an atom. The complex property of *being water* consists of the properties of *being hydrogen*, *being oxygen*, in a ratio of two to one respectively, and *bonded*. Finally, the simple approach looks like the natural place to begin. If we consider a typical ball-and-spring model for a molecule of methane, there are balls present representing each of the atoms, and there are springs representing bonding, and that's it. These models do not appear to represent any other constituents. Thus, we can say that the simple constitutive account accepts the following thesis:

SC: The exhaustive list of a chemical kind's constituents is given by its atomic or molecular model.

⁶⁰ Lewis (1986: 41) points this out, as does Hawley (2010).

The simple constitutive account also accepts another thesis, or rather, a set of theses concerning the nature of parts and wholes. There is debate within the philosophical literature about whether a constitutive account is governed by the formal system of *Classical Mereology* (CM).⁶¹ CM has a number of highly contested axioms, the principle of *Unrestricted Composition* for example perhaps being one of the most notorious. This principle states that for any class of objects, there exists the mereological sum of those objects. To illustrate the counterintuitive nature of this principle, it's customary to come up with an outrageous sounding mereological sum that one can think up, e.g. the mereological sum of the Panthéon, the first human child born in the year 2014, and my right big toe.⁶² The larger debate about use of the language of parts and wholes boils down to whether such talk is legitimate if it rejects the particular axiomatic system CM. As Hawley (2010) points out, there is a sense in which an account is constitutive without having to be committed to CM. Suppose however we begin with CM as a starting place, since not all of its principles are as counterintuitive as Unrestricted Composition. Another principle of CM we may call *Extensionality*, and it can be informally characterized as follows:

Extensionality – Two numerically different composite objects cannot be composed of exactly the same parts.

Here's how David Armstrong (1986), filling in the missing premise from David Lewis (1986a), puts it, “two different things cannot be composed of exactly the same parts” (85). Varzi (2008) points out that there are three principles often conflated in the literature. It seems that Armstrong's formulation is closest to what Varzi calls the *Extensionality of Parthood* (EP): if x and y are composite objects with the same proper parts, then $x = y$. Another principle,

⁶¹ See Appendix A for an overview of CM.

⁶² Despite its counterintuitive nature, there are several powerful arguments for it, see for instance Lewis (1986b) and Sider (2001).

Extensionality of Composition (EC), says: if x and y are composed of the same things, then $x = y$. Finally, the principle of *Uniqueness of Composition* (UC) says: if x and y are sums of the same things, then $x = y$. If Armstrong's theory violates either EP or EC, then UC goes as well. However, if as Varzi points out these principles are quite often conflated, it's not clear which of these principles Lewis thinks Armstrong's theory has violated since he doesn't explicitly state the one he invokes. However, Armstrong appears to think it's EP, so we'll just go with it. This principle is important for the discussion that follows in the next section, as it is used to generate a number of arguments against constitutive approaches in general.

In sum, the simple constitutive account also accepts CM for assessing the language of parts and wholes, in addition to the principle SC above. Thus, we can think of the simple constitutive account as the view that accepts SC+CM. The question is whether the simple constitutive account can handle other more complicated cases, ones involving more intricate structure. In other words, the big question for the constitutive account is whether it is *too simplistic*. In the next section I will discuss several cases involving isomers from chemistry, focusing first on structural isomers, in particular butane and isobutane, and second on cases involving chiral isomers, or enantiomers.

4.3 CHEMICAL ISOMERS

4.3.1 STRUCTURAL ISOMERS

Consider the chemical compounds butane and isobutane.⁶³ If these are natural kinds, then the proposal to characterize kinds in terms of complex structural properties has to give an account of

⁶³ Lewis (1986) objects to Armstrong's theory structural universals using this example. It should be noted that Lewis's objection specifically targets Armstrong's theory, which was a theory involving (1) immanent universals and (2) states of affairs. It might be thought that the strategies considered below fail to be true to the spirit of Armstrong's theory since the point of Lewis's

them. The simple constitutive account might begin with butane (whose molecular formula is C_4H_{10}) as follows. The complex property of *being butane* consists of the following constituent properties, *being carbon*, *being hydrogen* in a ratio of four to ten respectively, and *bonded*. But now consider isobutane (whose molecular formula is also C_4H_{10}). It would appear that the complex property of *being isobutane* consists of the very same constituent properties as *being butane*, namely, *being carbon*, *being hydrogen* in a ratio of four to ten respectively, and *bonded*. What's more, by the principle from earlier, *extensionality*, the properties *being butane* and *being isobutane* are the same. Call this the *extensionality objection*. The outcome that *being butane* and *being isobutane* are the same property is quite clearly false. It would appear that the simple constitutive account is committed to this blatant falsity. Those like Lewis (1986) take this as a sign that constitutive accounts in general should be rejected wholesale. This wholesale rejection I think comes too fast.

Butane and isobutane are structural isomers. They have the same molecular formula, but they differ insofar as they have differing physical structures. To illustrate, consider Figures 1 and 2 below.

objections was to force Armstrong into expanding his own ontology. Two things need to be said in reply. First, it's true that Armstrong was forced to confront the idea of complex structural universals as a result of Lewis's pressure, but Armstrong had already accepted a non-Lewisian ontology in defining structural universals in 1978 where his definition explicitly invokes *states of affairs*. Second, Lewis's (1986a) objections intend a more serious conclusion against the Armstrongian theory than the multiplication of higher-level entities, namely that of *logical incoherence*, since by 1986 Armstrong had already accepted a slightly less austere ontology. Thanks to Muhammad Ali Khalidi for raising this point.

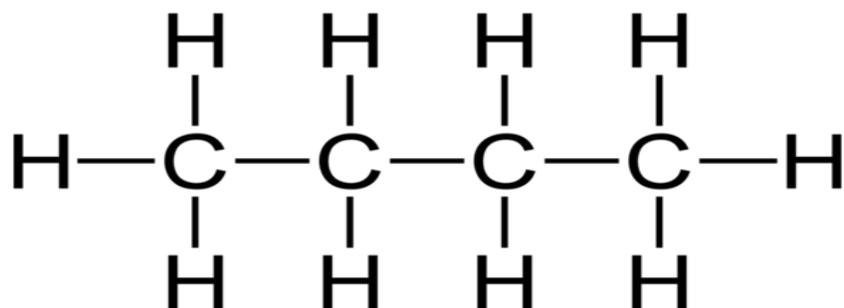


Figure 1: Structural Formula of Butane

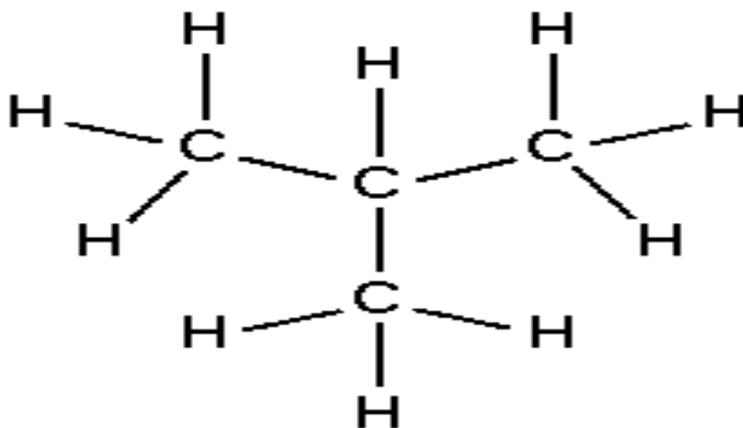


Figure 2: Structural Formula for Isobutane

What the Extensionality Argument evidently misses is the difference in *structural* arrangement of the constituents of butane and isobutane. While it might be thought butane and isobutane consist of the same parts, there is a clear difference between the two molecules in that their constituents bear different structural relations to one another. Perhaps then we should take this example to show like Lewis that the language of parts and wholes cannot be used for a theory of complex properties. Not yet, for the objection hinges on at least two factors. The first point is that the severity of the objection depends on how you answer a number of questions about properties. Second, and more importantly, the objection only poses a threat depending on how one interprets the structure of complex properties.

To see the first point, and to focus the objection for its intended target, let us begin with some traditional philosophical characterizations of properties. The foregoing discussion does not exhaust all options; in fact, the discussion involving Shoemaker's theory in the latter half of this essay does not fit neatly in the categories discussed below. But I want to highlight the idea that the Extensionality objection aims at a very specific sort of theory.

There are several distinctions often employed when discussing properties.⁶⁴ The first distinction is between things that are *universal* on the one hand, and *particular* on the other. Universals are usually (though not without controversy) characterized as entities that can be instantiated by more than one entity. If something cannot be so instantiated, then it is a particular. Realists about universals typically think properties like *being red*, relations like *being between*, or *being methane* are universals in that it seems that numerically distinct objects can instantiate these properties or relations.

There is a further distinction for those who accept universals, those who think universals are *transcendent* – that is that universals may exist apart from their instances – and those who think they are *immanent*, or have no existence apart from their instances. For the former, the universal of *wisdom* may still be said to exist, even in a world where there are no wise individuals. The immanent realist about universals will deny this. Finally, it's also customary to distinguish between something's being *abstract* versus something's being *concrete*. One way of drawing the distinction (again, not entirely without controversy) is to say that abstract objects are non-spatiotemporal entities. They exist, though neither in time, nor space, and are therefore also causally inert.⁶⁵ It's clear from these various distinctions that there are a variety of positions one

⁶⁴ The following taxonomy about properties is roughly that given by Armstrong (1989).

⁶⁵ Hale (1987) points out that games and languages, arguably abstract, come into and go out of existence at certain times (47). I'll ignore this detail in this characterization, since the point is

can take about properties, depending on what you think about these distinctions. However, the *extensionality objection* is not applicable to every theory of properties.

Trope theorists – those who think that properties are *abstract*, but *particular* – for instance won't be bothered by the problem, since no instance of *being butane* will have any part in common with any instance of *being isobutane*. The objection is directed specifically at those who hold that properties are universals, although it's not clear the objection applies equally to *transcendent* and *immanent* varieties. Thus, if you adopt one of these theories of properties, the objection will be of no concern to you.

Suppose we explore the strategy of construing the structure of butane and isobutane in a constitutive way, that is, suppose we reject SC of the simple constitutive account by claiming there is a structural part of butane that isobutane lacks, and there is likewise a structural constituent of isobutane that butane lacks.⁶⁶ How can we go about employing this strategy? One thing to observe is that in a butane molecule, each carbon atom is bonded to no more than two other carbon atoms within the molecule. This is not the case for isobutane, where in Figure 2, the center carbon atom is bonded to three distinct carbon atoms. Perhaps this structural difference can be exploited in some way that doesn't violate *extensionality*.

Pagès (2002) employs some semi-technical machinery that might help us with this strategy. According to Pagès, the important feature about structural universals is that they must be “construed in such a way that they bear certain traits relative to the numerical identity and difference of the particulars involved in the exemplifications of their constituent properties and relations” (217). To illustrate how the strategy is supposed to work, consider the following

just to illustrate how the extensionality objection yields different results for different theories of properties.

⁶⁶ See Koslicki (2008) who takes this strategy as a way to get out of the puzzles of material coincidence.

fictional chemical kinds, shmethane and isoshmethane, and their associated complex properties, *being shmethane* and *being isoshmethane*, whose molecular schemas appear below:



Like the structural isomers of butane and isobutane, shmethane and isoshmethane have the same molecular formula, i.e. ‘A₂C’. However, also like butane and isobutane, there is a difference in each as to which atoms are bonded together: with smethane, the lone C atom is bonded only to one other A atom, while with isosmethane the lone C atom is bonded to both A atoms. Also like butane and isobutane, shmethane instances and isoshmethane instances, would appear to have exactly the same kinds of constituents in exactly the same ratio, so according to the *extensionality* objection, they would appear to be the same chemical substances even though the chemical constituents have a different structural arrangement.

Similar appearances notwithstanding suppose we stipulate that these fictional chemical kinds are distinct. According to Pagès proposal, this is so since they actually involve numerically distinct “formal relations” (119). Let R be the formal relation indicated by the following open formula

$$(1) Cx \ \& \ Ay \ \& \ Az \ \& \ \text{Bonded}(x,y) \ \& \ \text{Bonded}(y,z)$$

and let S be the formal relation indicated by the open formula

$$(2) Ax \ \& \ Cy \ \& \ Az \ \& \ \text{Bonded}(x,y) \ \& \ \text{Bonded}(y,z)$$

Then, a sequence of three particulars instantiates the complex relation R if and only if the first particular is a C atom and it is bonded to the second particular, which is an A atom, and the second particular is bonded to the third particular, which is also an A atom. A sequence of

particulars instantiates S if and only if the first particular is an A atom, which is bonded to the second particular C atom, which is bonded to the third particular A atom. Thus, the complex structural properties of *being shmethane* and *being isoshmethane* have instantiation conditions as follows:

(3) Some thing *m* instantiates *being shmethane* if and only if there are particulars *a1*, *a2*, *a3* constituting *m* and different from each other such that the sequence $\langle a1, a2, a3 \rangle$ instantiates the relation R.

(4) Some thing *m* instantiates *being isoshmethane* if and only if there are particulars *a1*, *a2*, *a3* constituting *m* and different from each other such that the sequence $\langle a1, a2, a3 \rangle$ instantiates the relation S (218).

Another way we might capture the structural complexity for *being shmethane* and *being isoshmethane* is by way of polyadic λ -abstraction. Where ‘*a1*, *a2*, *a3*’ are constants standing for numerically distinct particulars, the structural features of *being shmethane* when given the sequence $\langle a1, a2, a3 \rangle$ as argument would look as follows:

(1') $[\lambda xyz (Cx \ \& \ Ay \ \& \ Az \ \& \ \text{Bonded}(x,y) \ \& \ \text{Bonded}(y,z))]\langle a1, a2, a3 \rangle$

And the structural features of *being isoshmethane*, when given the sequence $\langle a1, a2, a3 \rangle$ as argument might look like this:

(2') $[\lambda xyz (Ax \ \& \ Cy \ \& \ Az \ \& \ \text{Bonded}(x,y) \ \& \ \text{Bonded}(y,z))]\langle a1, a2, a3 \rangle$

One small difference between Pagès’ treatment and the λ -abstracts above is that ‘ λ ’ functions as a variable binding operator, and so the occurrences of the variables in those expressions are bound rather than free. Another small difference is that the λ -abstract is such that it explicitly shows that the sequence $\langle a1, a2, a3 \rangle$ is taken as argument for the expression. In both cases, these differences are minor, as both characterizations ultimately rely on the same underlying strategy to get a difference between isomers.

Thus on this account, the complex properties of *being shmethane* and *being isoshmethane* are composed of different constituents: the complex property of *being shmethane* consists of *being C*, *being A*, *bonded*, and the formal relation *R*, while the complex property of *being isoshmethane* differs from *being shmethane* in that the relation *S* is a constituent of it. *Being shmethane* and *being isoshmethane*, contrary to their initial appearance, do not violate the mereological principle of *extensionality* since there is a difference in parts that explains the distinctness of the complex properties. What's more, the general strategy applied here, Pagès remarks, can easily be applied to the case of butane and isobutane, *mutatis mutandis*.⁶⁷ In effect, this strategy denies the thesis of SC from the simple constitutive account. In other words, it's not the case that complex chemical kinds with the same chemical formula share all of the same constituents.

Can we use this strategy more generally as a way to capture the structural relations for all other chemical kinds? Pagès strategy observes that “structural universals must be construed in such a way that they bear certain traits relative to the numerical identity and difference of the particulars involved in the exemplifications of their constituent properties and relations” (217), by way of constructing distinct formal relations that are instantiated by sequences of particulars. However, there are some cases from chemistry for which this strategy is problematic.

4.3.2 ENANTIOMERS

Chirality is a property of asymmetry. Something is *chiral* (from the Greek word “*χειρ*”, or “hand”) if it cannot be superimposed onto its mirror image. One of the most familiar pair of chiral objects comes in the form of the human left and right hands. Human left and right hands, though similar in many respects, are not identical in that no matter how one orients them, the

⁶⁷ See Pagès (2002) note 5 for the fully articulated proposal for butane and isobutane.

major features of a left hand do not coincide with those of a right hand. This fact is particularly salient when one attempts to fit a left-handed glove on the right hand. A chiral object and its mirror image are called *enantiomorphs*, while an object that can be superposed onto its mirror image is *achiral*.

Chirality is common phenomenon, and there are cases of chiral objects ranging from mathematics, physics, chemistry, to biology. In chemistry chiral molecules are called *enantiomers*, and Figure 3 below shows two enantiomers of a generic (α) amino acid.

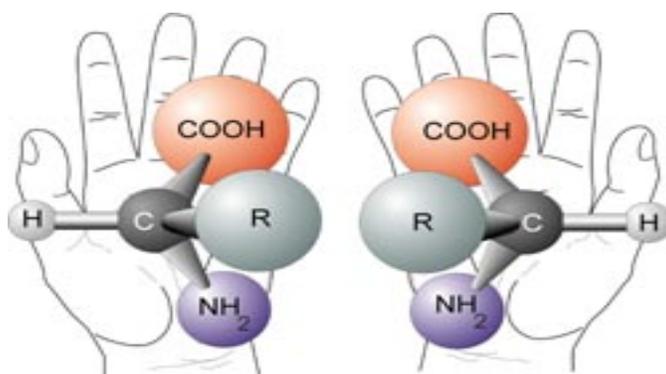


Figure 3: Two Enantiomers of Generic Amino Acid⁶⁸

What makes enantiomers particularly difficult for the simple constitutive account is that they involve structural features quite different from the structural isomers of butane and isobutane. In particular, the strategy discussed in the previous section for handling structural isomers appears somewhat problematic for enantiomers. Consider the two generic amino acids, the S-enantiomer ('S' for the Latin *sinister*) and the R-enantiomer ('R' for the Latin *rectus*) from left to right respectively, pictured above in Figure 3. Each has the chemical formula $C_2H_4NO_2$. As we saw with butane and isobutane, it was thought that sameness of chemical formula implied sameness

⁶⁸ The 'R' pictured in this illustration indicates a side-chain specific to the amino acid, in this case, the α -carbon atom, which is the one attached to the carboxyl group above it. The R-'element', therefore does not represent an actual elemental constituent in the same way that the carbon atoms, for example, are.

of parts of the complex property, and therefore appeared to violate *extensionality*. We saw that Pagès strategy was to deny the implication from sameness of chemical formula to sameness of parts by describing two distinct relations for butane and isobutane, and so one might try a similar strategy for the S-enantiomer (Left) and the R-enantiomer (Right). Let S' denote the following formula:

(5) $Cx_1 \ \& \ Cx_2 \ \& \ Hx_3 \ \& \ Hx_4 \ \& \ Hx_5 \ \& \ Hx_6 \ \& \ Nx_7 \ \& \ Ox_8 \ \& \ Ox_9 \ \& \ \text{Bonded}(x_1,x_2) \ \& \ \text{Bonded}(x_1,x_7) \ \& \ \text{Bonded}(x_7,x_3) \ \& \ \text{Bonded}(x_7,x_4) \ \& \ \text{Bonded}(x_1,x_5) \ \& \ \text{Bonded}(x_2,x_8) \ \& \ \text{Bonded}(x_8,x_6) \ \& \ \text{Bonded}(x_2,x_9)$

Let's then say that something instantiates the property of *being an S-enantiomer of a generic amino acid* along the following lines:

(6) Some thing *m* instantiates *being an S-enantiomer of a generic amino acid* if and only if there are particulars $a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9$ constituting *m* and different from each other such that the sequence $\langle a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9 \rangle$ instantiates the relation S'.

Similarly, let's say that R' denotes the following formula:

(7) $Cx_1 \ \& \ Cx_2 \ \& \ Hx_3 \ \& \ Hx_4 \ \& \ Hx_5 \ \& \ Hx_6 \ \& \ Nx_7 \ \& \ Ox_8 \ \& \ Ox_9 \ \& \ \text{Bonded}(x_1,x_2) \ \& \ \text{Bonded}(x_1,x_7) \ \& \ \text{Bonded}(x_7,x_3) \ \& \ \text{Bonded}(x_7,x_4) \ \& \ \text{Bonded}(x_1,x_5) \ \& \ \text{Bonded}(x_2,x_8) \ \& \ \text{Bonded}(x_8,x_6) \ \& \ \text{Bonded}(x_2,x_9)$

And like before, we'll say that the conditions for something's instantiating the property *being an R-enantiomer of a generic amino acid* as follows:

(8) Some thing *m* instantiates *being an R-enantiomer of a generic amino acid* if and only if there are particulars $a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9$ constituting *m* and different from each other such that the sequence $\langle a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9 \rangle$ instantiates the relation R'.

The trouble, is that (5) and (7) will work just as well as formulas describing the structure of both the S-enantiomer, and the R-enantiomer, and so (6) and (8) give the conditions for something's instantiating the property of *being an S-enantiomer* as well the conditions for something instantiating the property of *being an R-enantiomer*. In other words, these supply instantiation conditions for both Left- and Right-handed enantiomers, which means these formal relations cannot function as the distinguishing constituents for these chemical kinds. Thus, pursuing the same strategy that worked for structural isomers cannot be simply transferred over to the case of enantiomers, since both Left- and Right-handed enantiomers will consist of the same constituents: *being carbon, being hydrogen, being nitrogen, being oxygen, bonded*, and either the equivalent S' or R'. Hence, the Extensionality Objection still applies.

One might resist this line of reasoning, however. One reply might be to deny that enantiomers are really distinct chemical kinds, since we do in fact say that both the S-enantiomer and R-enantiomer are enantiomers of the same generic α -amino acid. This reason alone however does not give us good reason to think that enantiomers are the same. While it's true that both Left and Right enantiomers are both members of another higher kind, given the very hierarchical nature of kinds, it's clear that two distinct kinds can both be members of another higher kind. The elements listed of the periodic table are all distinct, though they all fall under the larger kind *atomic element*. What's more, to claim that two enantiomer kinds are the same kind is untenable for several other reasons.

The first reason to think enantiomers are distinct is from the definition of chirality itself, which just says that something is chiral when it is not superimposable onto its mirror image. Beyond that, it's possible to give topological criteria to determine molecular chirality in terms of

or potentially even deadly. One might then say that each enantiomer has a *dispositional* property the other one lacks, and this gives us a reason to distinguish them from one another.

However, we need to be careful how this is formulated. Slater (2005) points out a potential circularity worry for those who are tempted by this dispositional move. If what makes an L-enantiomer distinct from its right counterpart is that it reacts differently in asymmetric environments, that is, that it reacts differently with other *distinct enantiomers*, we have already presupposed the distinctness of Left- and Right-handed enantiomers, which is precisely what we were attempting to show were distinct from the outset. Fortunately, there is another way to proceed without circularity. We'll take as starting point the nomenclature, '-' and '+', already used in chemistry to distinguish enantiomers by appealing to the direction by which the enantiomer rotates the plane of polarized light.⁷¹ If the enantiomer rotates the plane of polarized light in a clockwise direction, that enantiomer is said to be *dextrorotatory* and is assigned '+', while if the enantiomer rotates the plane of polarized light in a counterclockwise direction, the enantiomer is said to be *levorotatory* and is assigned '-'. So according to this strategy, the constituents of one enantiomer will consist of *being carbon, being hydrogen, being nitrogen, being oxygen, bonded*, the complex relation *S'*, and the further constituent *being levorotatory*, while the other enantiomer will differ in that it will have as a constituent the property of *being dextrorotatory*.

⁷¹ Another system developed by Cahn, Ingold, and Prelog (1966) involves a set of rules (the 'CIP' Priority rules) that assign a priority to the substituents of a chiral molecule based on atomic number. If one begins with the chiral center, typically an asymmetric carbon atom for most organic compounds, and an observer orients herself such that the substituent with the lowest number is pointed away from her, then the enantiomer whose substituents' atomic numbers decrease in a *clockwise* direction are labeled 'R' (*rectus*, or 'right'), while those whose substituents' atomic numbers decrease in a *counterclockwise* direction are labeled 'S' (*sinister*, or 'left'). See for instance (Stephens, Devlin, et al. 2003).

In this section I've argued that the simple constitutive account for chemical kinds is far too simplistic to handle chemical isomers, and I've outlined several strategies one can adopt to get around the objection posed by potential violations of the mereological principle of *extensionality*. That strategy involved two parts: first, the denial of the claim that the constituents of a complex chemical property like *being butane* are given by its molecular formula, and second it provided semi-formal criteria to capture the structural complexity of properties like *being butane* and *being isobutane*. As we saw, however, the strategy to give purely structural criteria for distinguishing between chemical kinds faced a challenge from chemical enantiomers. The strategy suggested was to differentiate the enantiomers by their causal behaviors. In the next section, I want to motivate the idea that causal notions are often very important in distinguishing different chemical kinds from one another.

4.4 CHEMICAL KINDS AND CAUSAL DIFFERENCES

I mentioned in the previous section that there are other reasons to consider enantiomers distinct chemical kinds. The reason is that under certain circumstances, two enantiomers of the same chemical kind will behave quite differently. This section will try to motivate the idea that another important aspect left out of the picture of kinds given by the simple constitutive account is that of causal structure. If we allow for the possibility of constituents other than those identified in a chemical kind's molecular formula, as the previous structural strategy supposed, then it's also plausible to go on to identify other constituents, provided of course there is no principled reason against doing so. This causal strategy, like the structural strategy from the previous section, denies the simple constituent thesis of SC.

Let's return to butane and isobutane, and the respective complex properties *being butane* and *being isobutane*. We saw that the two properties of the structural isomers differed with

respect to how constituents of their instances are bonded to one another. But there are other ways in which butane and isobutane differ in that they often have different practical purposes. Butane is often blended with other hydrocarbons like propane and used for fuel, as for instance in cigarette lighters, and it's used as a propellant in aerosol sprays. Isobutane is used as a refrigerant in domestic refrigerators, and is also used as a propellant in aerosol cans. Moreover, butane and isobutane differ in other noticeable ways, some of which are listed side-by-side for comparison below in Table 1:

Butane	Isobutane
Odor: petrol-like	Odor: odorless
Density: 2.48 kg/m ³ (at 15°C)	Density: 2.51 mg/ mL ⁻¹ (at 15°C, 100 kPa)
Melting Point: -140 to -134 °C; -220 to -209 °F; 133 to 139 K	Melting Point: -233.2 to -33.1 °C; -387.7 to -27.7 °F; 40.0 to 240.0 K
Boiling Point: -1 to 1 °C; 30 to 34 °F; 272 to 274 K	Boiling Point: -13 to -9 °C; 8 – 16 °F; 260 to 264 K

Table 1: Causal Differences Between Butane and Isobutane

What Table 1 illustrates is that butane and isobutane behave quite differently in certain circumstances. They are different with respect to odor, density, melting and boiling points. These differences are important since, as I'll try to motivate in the subsequent section, these causal differences are relevant for giving the individuation conditions for complex properties like *being butane* and *being isobutane*.

The next interesting question is whether enantiomers also have relevant causal differences. As we saw in the previous section, a significant difference between structural isomers and enantiomers was that the former isomers have structural differences in the way that the parts of the instances are spatially arranged, while with enantiomers the difference lies in the fact that their images cannot be superimposed onto one another. Because of this similar

structure, enantiomers behave nearly identically in most environments; in other words, in symmetrical environments, their causal properties are identical (with the exception of rotating plane-polarized light). These causal properties differ however when the enantiomers are in asymmetric environments. As I briefly mentioned above, these differences are especially salient in pharmacology, where one enantiomer of a drug may have salubrious or healing effects, while the other enantiomer is toxic. Goozner (2005) details how the ability to separate enantiomers, the research for which was developed in the 1990s by the chemists K. Barry Sharpless, Ryoji Noyori, and William Knowles, all of whom jointly shared the 2001 Nobel Prize for chemistry, had profound effects in pharmacology and the drug manufacturing industry:

The new process succeeded in rescuing some drugs that had been sidelined for their unwanted side effects. In 1992, for instance, the FDA ordered Merrell Dow, which later became part of Aventis, to put a warning label on its allergy drug terfenadine (Seldane) after adverse reaction reports began pouring into the agency. Doctors who prescribed the nonsedating antihistamine for their allergy patients reported many terfenadine users had suffered severe heart palpitations after taking the drug. Six years and at least eight deaths later, it was withdrawn from the market. But the drug was resuscitated when a special chemical company called Sepracor separated the two enantiomers of terfenadine for Aventis, which was then able to continue marketing the safe but active half. They called it Allegra. Sepracor later performed the same trick for Johnson and Johnson after its allergy drug astimezole (Hismanal) suffered a similar fate (221).

Other drugs whose enantiomers have markedly different causal effects include Ethambutol, Naproxen, Methorphan, and the drugs amphetamine and methamphetamine. Let me describe one more compelling example. Glucose, also called *D-glucose*, is one of three common dietary monosaccharides, the others being *fructose* and *galactose* (each of which also share the same chemical formula $C_6H_{12}O_6$). Glucose is frequently found in nature, and in biology it is an important carbohydrate as many organisms use it as a source of energy. In humans, it is the

human body's main source for energy through aerobic respiration. Contrast this with the stereoisomer of D-glucose, L-glucose. L-glucose is not naturally occurring, although it can be synthetically produced. Unlike D-glucose L-glucose cannot be used by the human body as a source of energy because it cannot interact with the enzyme *hexokinase* for the phosphorylation process.

What these examples serve to illustrate is that there are relevant causal differences between chemical isomers. These causal differences are important for several reasons. First of all, these differences are empirically observable in that we can empirically test to see the different causal effects that Left- and Right-handed enantiomers will have. Next, these differences serve a number of practical purposes, for instance in medicinal contexts like drug prescription, as taking one enantiomer may cause "severe heart palpitations" while the other may alleviate your allergies. This suggests that distinguishing causal differences gives us good evidence for supposing that causal criteria play an important role in distinguishing kinds. Thus, causal differences give us *prima facie* evidence for thinking that Left- and Right-handed chemical enantiomers are *distinct kinds*.

If Left- and Right-handed chemical enantiomers are numerically distinct kinds, but they have the same constituents, then this is a violation of the Extensionality principle. My suggestion around this objection is to offer the following for consideration. The causal differences between distinct chemical isomers suggest that different isomeric kinds also have different *causal properties*. Moreover, these causal properties are also *constitutive* of the more complex properties of which they are parts. Consider, the distinguishing property in the case of the Left- and Right-handed enantiomers for the generic amino acid mentioned earlier are themselves causal properties: the property of *being capable of rotating plane polarized light in a*

counterclockwise direction (being levorotatory) and the property of *being capable of rotating plane polarized light in a clockwise direction (being dextrorotatory)*. Since one enantiomer will have the property of *being levorotatory*, while the other enantiomer will have the property of *being dextrorotatory*, there will be a difference in their constituents contrary to the simple constitutive thesis of SC. This strategy would bypass the Extensionality Objection.

In the next section I want to elaborate on what I earlier called *causal structure*. The aim will be to give a clearer picture of what is meant by a causal property. To do so, I will examine Sydney Shoemaker's causal theory of properties. In particular I want to elaborate on his idea of a *conditional causal property*. The very general idea behind this is that the causal effects of causal properties only manifest themselves under certain conditions. Just as a glass with the property of *being fragile* only breaks when it is, for example, dropped onto a hard surface, the different causal effects for chemical enantiomers also become evident only under certain conditions. In particular, the causal differences between enantiomers are evident only under certain *structural* conditions. Shoemaker's theory will allow me to focus the claim for which I've been arguing: that causal considerations play a significant role in the individuation of chemical natural kinds.

4.5 SHOEMAKER ON PROPERTIES

Sydney Shoemaker (1980) elucidated the causal theory of properties in several ways. As Troy Cross (2012) points out, although Shoemaker was by no means the first to propose a causal theory of properties – precursors included those like Achinstein (1974), Harre and Madden (1975), and Putnam (1970) among others – he is notable for developing the view in several novel respects. In what follows I shall give an overview of this theory, and I will use it as a way to develop the idea of the causal structure of natural kinds. Although Shoemaker goes on to discuss (and in some cases abandon certain parts of) his theory in subsequent essays (e.g. Shoemaker

2001, 2003), my discussion will focus on the formulation from 1980, as that essay makes use of the notion of a causal *power*, which is slightly downplayed (though importantly never altogether abandoned) in subsequent discussion.

Shoemaker begins with the observation that our intuitions about which properties are real or genuine are tied closely to our intuitions about real or genuine changes. In contrast with the view endorsed later in the essay, Shoemaker first introduces what he ultimately thinks is an inadequate criterion for determining change from Peter Geach (1969), which Geach dubbed the “Cambridge Criterion”. For some particular thing *a* at a time *t* and a subsequent time t_1 , the thing denoted by ‘*a*’ has changed if

$$(9) Fa \text{ at } t$$

is true, while

$$(10) Fa \text{ at } t_1$$

is false, for some interpretations of ‘F’, ‘*t*’, and ‘ t_1 ’. But as both Geach and Shoemaker point out, this criterion gives the counterintuitive result that “Socrates undergoes change when he comes to be shorter than Theaetetus in virtue of the latter’s growth, and even that he undergoes a change every time a fresh schoolboy comes to admire him” (Shoemaker 1980: 110). Such a change, one that is intuitively not a genuine change, they call a “mere ‘Cambridge’ change”, and Shoemaker applies the expressions “Cambridge” and “mere-Cambridge” to delineate different sorts of changes, properties, resemblance and similarity, and differences. The point in distinguishing Cambridge changes from the mere-Cambridge changes, however, is that there is there is genuine philosophical discussion needed here, one that goes beyond purely linguistic matters about truth and falsity of sentences. In other words, Geach’s Cambridge Criterion says nothing about what

constitutes *change*. This is a metaphysical issue and one that Shoemaker thinks is tied closely to *causation*.

Shoemaker next turns his sights to the nature of properties. What he offers can be described as a “neo-Lockean” theory in that there are some interesting parallels between Shoemaker’s view about properties and what Locke called “secondary qualities”. Shoemaker, citing Locke’s *Essay* 2.23.8, which reads, “powers make a great part of our complex ideas of substances”, goes on to emphasize the apparent claim about “powers”.⁷² For Locke, secondary qualities of objects include things like color and temperature. Objects with the secondary quality of being blue have the *power* to cause in us a particular sensation, and objects in possession of the secondary quality of coldness have the *power* to cause in us cold sensations. Locke’s primary qualities by contrast are those qualities like *shape* and *spatial extension*.⁷³ Locke also recognized other powers aside from secondary qualities, tertiary qualities, which are “powers (for example, the power in the sun to melt wax) to produce effects in material objects” (Shoemaker 112). Thus the point of contact between Locke and Shoemaker comes in the form of *causal powers* and their relationship to properties. “What would seem to be the same view”, writes Shoemaker, “is sometimes put by saying that all properties are dispositional properties” (112). However, there is a distinction between something’s being *dispositional* and something’s having powers in the sense Shoemaker advocates.⁷⁴

⁷² See Locke (1894).

⁷³ Primary qualities are supposed to be distinguished from secondary qualities in that the former depend in some way on us, while the latter do not.

⁷⁴ Some like Choi and Fara (2014) credit Shoemaker with the view called *Dispositional Essentialism*, which holds that all properties are dispositional in nature. Others like Bird (2007) say that Shoemaker anticipates that view, but avoids directly attributing it to him. It is far from clear that Shoemaker held that thesis in this essay, especially if we assume that the quantifier ‘all’ is taken unrestrictedly, since he explicitly rules out mathematical properties like *being even* and *being prime* (Shoemaker 1980: 112). Rather, the theory is supposed to apply only to those

According to Shoemaker, “dispositional” is a term for linguistic items, namely predicates:

Sometimes it belongs to the meaning, or sense, of a predicate that if it is true of a thing then under certain circumstances the thing will undergo certain changes or will produce certain changes in other things. This is true of what are standardly counted as dispositional predicates, for example ‘flexible’, ‘soluble’, ‘malleable’, ‘magnetized’, and ‘poisonous’. Plainly not all predicates are of this sort. Whether color predicates are is a matter of controversy. But whatever we say about this, it seems plain that predicates like ‘square’, ‘round’ and ‘made of copper’ are not dispositional in this sense. There are causal powers associated with being made of copper – for example, being an electrical conductor. But presumably this association is not incorporated into the meaning of the term ‘copper’ (113).

One might elaborate on Shoemaker’s reasoning here as follows. Dispositional predicates like ‘is poisonous’, ‘is soluble’, and ‘is fragile’ are such that the powers associated with things to which the predicates apply are in some sense part of the meanings of the expressions themselves, while this is not true (in general) for predicates like ‘is copper’, ‘is methane’, or ‘is potassium’. Since Shoemaker’s point is a linguistic one, we might employ another well-known linguistic device to help illustrate. Universal sentences formed using dispositional expressions like “All soluble things are things that dissolve in water”, and “All fragile things are things prone to break easily”, are analytically true. By contrast, universal sentences formed with non-dispositional expressions like, “All copper conducts electricity” and “All round things are things that have the power to roll” are not analytically true. And Although Shoemaker appeals to similar reasoning later in the

properties “with respect to which change is possible”. Presumably Shoemaker means something like “genuine change” since the mere-Cambridge property of *being prime and being such that Barack Obama is current President of the US at t*, is true of the number two where ‘t’ is the year 2014, while the property of *being prime and being such that Barack Obama is current President of the US at t₁*, where ‘t₁’ is 2018, is false of two at that later time.

essay, that discussion arises in the context of forestalling the objection that his theory has the result that causal laws are analytic and knowable *a priori*, rather than as a means to draw the distinction between dispositional and non-dispositional predicates. The upshot to this linguistic distinction I think is two-fold. It serves to point out that there is something important going on at the metaphysical level that is not captured by drawing a merely linguistic distinction, like that given by Geach's Cambridge criterion from earlier, and the example of 'copper' serves to highlight the connection between natural kind terms and causal powers. We can think of this second point as giving us *prima facie* linguistic evidence for supposing the causal relationship between copper and various causal powers associated with it.

The other distinction pertains to *causal powers*, and "the properties in virtue of which things have the powers they have" (113). A power according to Shoemaker can be thought of as "a function from circumstances to effects" (113). To illustrate, suppose we have the function, $\langle C_1, E_1 \rangle$, such that an object that possesses the power *to P* in circumstance C_1 will have the effect E_1 . For example, if some substance has the power *to poison* (hemlock, let's say, or the species *Conium maculatum*), then that substance's presence in someone's body will have the effect of producing death or illness. By "circumstances", Shoemaker has in mind "the relations of the object to other objects..." (134). We can then think of the circumstances C_1 as a set of relations an object enters into. Socrates' fatal hemlock draft would have had no fatal effect on him were it to have remained outside of his body. Once ingested, however, hemlock's power to poison then produced the effect E_1 , the death of Socrates. Thus, "in virtue of this, being poisonous is a

power” (113).⁷⁵ The phrase “in virtue of” in this context is intended to have *nomic force*, as Shoemaker makes clear in an endnote:

What does “in virtue of” mean here? For the moment we can say that a thing has a power in virtue of having certain properties if it is a lawlike truth that whatever has those properties has that power. On the theory I shall be defending it turns out that this is a matter of the possession of the properties entailing the possession of the power (that is, its being true in all possible worlds that whatever has the properties has the power) (134).

The idea is that these nomic connections obtain when an object with certain properties enters into certain circumstances, which then causally results in certain effects. The emphasis on these ‘lawlike’ connections is especially important for Shoemaker’s view for two reasons. First, Shoemaker’s assessment of properties relies on this more robust notion of causation, that is, he intends his theory to have “some strikingly non-Humean consequences” (110). Second, these ‘lawlike’ connections are invoked for when he gives the identity conditions for properties.

What makes a property the property it is, what determines its identity, is its potential for contributing to the causal powers of the things that have it. This means, among other things, that if under all possible circumstances properties *X* and *Y* make the same contribution to the causal powers of the things that have them, *X* and *Y* are the same property (114).

Another way of describing the nature of properties, one which I think mirrors Shoemaker’s account, is given by Hawthorne (2001), who says that a property’s causal profile – the set of powers a property bestows on its instances – exhausts the nature of the property.

To illustrate further using a favorite example from Shoemaker, consider the property of *being knife-shaped*. This property, by itself (so to speak), need not confer the power *to cut wood*

⁷⁵ In what follows I will try to adhere to the convention employed in the last few sentences where powers are named by italicized occurrences of full-infinitive verb forms, e.g. ‘*to poison*’, ‘*to expire*’, ‘*to melt at a certain temperature*’, and so on.

on objects instantiating that property; if an object instantiating *being knife-shaped* is made of a soft material like balsa wood, then the property won't bestow the power *to cut wood*. However, if the property of *being knife-shaped* enters into other circumstances, say when that property is combined with other properties like *being made of steel* and *having a sharp edge between 12° - 18°*, then these circumstances combined with the property of *being knife-shaped* are "causally sufficient" (115) for an object having the power *to cut wood*. Moreover, the property of *being knife-shaped* when combined with other properties, like *being made of glass*, will result in slightly different causal powers being conferred on the object instantiating those properties.⁷⁶

What is the relationship between properties and powers? Are properties just powers, that is, are properties just identical with clusters of powers, or instead do properties *confer* powers to the objects that instantiate them, but are not to be identified with those powers? Mumford (2004) Ch. 10 and Mumford and Anjum (2011: 3) for instance think that Shoemaker held the latter view in the essay currently being discussed, that is the view that properties just are powers, but they maintain that he changed his mind later on, for example in Shoemaker (1999: 297) where the claim is that properties *bestow* powers on their instances. While there are passages that suggest one interpretation – e.g. the passage on the previous page where he gives the identity conditions for properties in terms of what powers they contribute to objects that have them – and others suggesting the strong identity claim – like, “we can express my view by saying that properties are clusters of conditional powers” (115) – I am inclined to proceed with the view that properties bestow powers on their instances for several reasons. First, as I've already mentioned, the

⁷⁶ Pye (1996) presents empirical linguistic evidence against the view that there are universally shared concepts for events of cutting and breaking. Even stronger, Pye claims the cross-linguistic evidence from the K'iche' Maya language compared to say an English list of verbs of cutting and breaking supports a more radical Quinean thesis about the referential indeterminacy of language more generally. See also Majid et al. (2007) for further discussion.

language employed throughout Shoemaker's essay fluctuates between those passages which appear to support one view, and then another, so it's at least not obvious that the properties-are-powers view is the one Shoemaker intended throughout the essay. Second, as Mumford and Anjum themselves state, Shoemaker clarifies his own position in subsequent writings and recants on the properties-as-powers position. Finally, if we were to assume that Shoemaker is offering an *analysis* of properties as powers as an attempt to give metaphysical foundations for the notion of a property, his account would be viciously circular instead of virtuously so. As Troy Cross (2012) remarks,

Since the function by which Shoemaker individuates properties itself takes properties as arguments, and the circumstances and effects are a matter of which properties are instantiated where, he is forced to acknowledge, and embrace, the non-well-foundedness of his proposal. Still, just as the individuation of sets by their elements and the individuation of ur-elements by the sets to which they belong is informative, though ultimately circular, Shoemaker's theory promises us a non-trivial, substantive constraint on the identity of properties (4).⁷⁷

As Cross points out, Shoemaker's theory still provides us with an informative and importantly non-trivial account of the identity conditions for properties. A fully reductive analysis of properties in terms of powers, that is an ontological theory seeking to replace talk of properties with clusters of powers, would fail to provide the needed grounding for properties, and hence would fail to be virtuous.

The last item to discuss is Shoemaker's notion of a *conditional power*:

Let us say that an object has power P conditionally upon the possession of the properties in set Q if it has some property r such that having the properties in Q together with r is

⁷⁷ Page references here are to the version available online at <http://philpapers.org/archive/CROGHS.pdf>.

causally sufficient for having P , while having the properties in Q is not by itself causally sufficient for having P (115).

Returning to the knife example, suppose that an object has some power, e.g. the power *to cut wood* (power P), which is conditional on possession of other properties, like the property of *being made of steel, having a sharp edge between 12° - 18°*, etc. (the properties of set Q), which when combined with the property of *being knife-shaped* (property r), is causally sufficient for possessing the conditional power in question. Note, that possession of the property r alone, i.e. *being knife-shaped* is not itself causally sufficient to bestow the power *to cut wood*.⁷⁸

The key points to take away from Shoemaker's discussion on the nature of properties revolve around the central idea that certain properties instantiated by an object confer certain causal powers on that object. Furthermore, these causal connections are not merely accidental features associated with the properties. Rather, as Shoemaker intended, there are robust nomic relations that obtain between certain properties and others. In what follows, I use Shoemaker's theory to elucidate the notion of causal structure for both structural and optical isomers discussed in previous sections. If as I argued in previous sections, there are structural properties associated with the kinds in question, it's precisely these structural properties that are important for the causal powers possessed by members of the kind. We can make use of the idea of Shoemaker's conditions, that is "the relations of an object to other objects" as a way to capture the structural relations of chemical isomers, and these structural relations can be used to specify the conditions under which chemical isomers have the causal powers they have.

⁷⁸ In addition to giving a very detailed account of Shoemaker's overall metaphysical theory, including his theory of properties, the relation to natural laws, and implications for multiple realizability in the philosophy of mind, Zimmerman (2009) provides us with a convenient semi-formal shorthand for naming Shoemaker's conditional powers. Since my aim here is not primarily one of exegesis, I will continue using Shoemaker's own formulations instead of adopting Zimmerman's.

4.6 CAUSAL STRUCTURE AND NATURAL KINDS

I have been articulating a view where natural kinds are complex, structural properties, the constituents of which are causally linked to certain conditional powers, which as I claim, are also themselves constitutive of the kinds. To see how the view is supposed to be applied, let's return to discussion of chemical isomers from earlier, beginning with the structural isomers of butane and isobutane. In Section 4.3 above we saw that *being butane* and *being isobutane* had the same molecular constituents since they share the same molecular formula, but it was argued that the kinds differ from one another in having different structural properties which were we were able to formally capture with the strategy outlined by Pagès. In Section 4.4 it was shown how the difference in these structural properties makes a difference to the causal behavior of members of those kinds, and it was claimed that the causal structure of chemical kinds was also constitutive of those kinds. Shoemaker's causal theory of properties gives us a way to make this idea a little more clear. The key point is to use the idea of a conditional causal power to make sense of the fact that structural features of a kind are related to how that kind will behave causally.

Consider again butane and isobutane, and reconsider Table 1, which highlights various differences between the two kinds. For the sake of simplicity, I'll focus on the differences in boiling point, which for butane is -1 to 1 °C and for isobutane is -13 to -9 °C. The reason why these two kinds differ in boiling point despite having the same molecular formula can be attributed to the structural arrangement of their constituents. Although there are a number of other factors influencing the boiling point of substances (atmospheric pressure, salinity levels, etc.) I will only briefly discuss those relevant for the current example. First, we need to consider the strength of the intermolecular forces – ionic, hydrogen bonding, dipole-dipole, and the Van der Waals' dispersion forces. In general, the more branching that occurs in the structure of a

molecule, the lower the boiling point. This is so since the straighter a molecule, the greater its surface area. This in turn means it can form more dispersion interactions than rounder molecules. Thus, isobutane's branching structure accounts for its lower melting point.

With Shoemaker's idea of a conditional causal power at our disposal, we can now specify the conditions under which isomers will have the powers that they have. This can be accomplished by building the structural features of isomers into the conditions for which an isomer has the powers that it has. Suppose now that we let S^*_1 be the structural properties of the complex property *being butane*, and we let S^*_2 be the structural properties of the complex property *being isobutane*. Then, we can say that an object of the kind *being butane* will have the power M_1 , *to melt between -1 and 1 °C*, conditional on instantiating the properties of or entering into the relations from set Q (e.g. properties involving the constituents of butane like *being carbon*, etc.), and the structural property S^*_1 . Having both the property S^*_1 and those properties from set Q is causally sufficient for having the power M_1 , *to melt between -1 to 1 °C*, though having the properties in set Q alone is not causally sufficient for having that power. Thus, the causal power M_1 , *to melt between -1 to 1 °C* can be thought of as a function from a set of properties and conditions Q to an effect, namely, the event of a particular molecule of butane melting between -1 to 1 °C, or $\langle Q, M_1 \rangle$. Similarly, an object of the kind *being isobutane* will have the power M_2 , *to melt between 13 and -9 °C*, conditional on instantiating the properties of set Q' , and the structural property S^*_2 . Having both the structural property S^*_2 and instantiating the properties of set Q' is causally sufficient for having the power M_2 . These powers, which depend on the properties of the sets just mentioned along with the structural properties indicated, are also constitutive of the complex properties. Thus, in virtue of the differences in their causal constituents, *being butane* and *being isobutane* are distinct chemical kinds.

Enantiomers present a slightly different challenge. The reason lies with the fact that the strategy for distinguishing Left- and Right-handed enantiomer kinds in Section 4.3 relied on the kinds behaving differently in different environments. In the case of the optical criterion, the relevant properties distinguishing the enantiomers from one another were the property of *being levorotatory* (indicated with a ‘-’) and the property of *being dextrorotatory* (indicated with a ‘+’), that is, rotating the plane of polarized light in either a counterclockwise or clockwise direction respectively. Using the language of powers from Shoemaker, we can say that (-)-enantiomers (levorotatory) have the power *to rotate the plane of polarized light in a counterclockwise direction* while (+)-enantiomers (dextrorotatory) have the power *to rotate the plane of polarized light in a clockwise direction*. The trouble is that using Shoemaker’s language of conditional powers now raises the following question: on what conditions do these different powers depend?

In the case of optical enantiomers, the conditions required for the manifestation of the distinguishing powers involve being in certain sorts of environments, asymmetric ones, for instance environments found in the human body. The very notion of chirality itself and the criterion of non-superimposability to distinguish chiral objects from one another are tied to the topological notion of *orientability*. A (Euclidean) surface is said to be *orientable* if a two-dimensional figure in that space cannot be moved continuously around the space and back to its original position so that it looks like its mirror image, otherwise the surface is *non-orientable*. The *mobius strip* pictured below in Figure 4 is a non-orientable surface.



Figure 4: Image of Möbius Strip⁷⁹

Supposing then that the powers specific to enantiomers manifest themselves only in specific sorts of environments, we can say that powers constitutive of enantiomers manifest themselves only under certain conditions. Thus, the conditions of a set Q' under which an enantiomer's powers will manifest themselves may include things like *being in an asymmetric environment* or *being in an orientable space*. Just as we can talk about the disposition of *fragility* in terms of the power *to break under a certain amount of stress*, where the conditions under which a glass breaks can be specified in those conditions, we can also talk about the conditions under which an enantiomer will react in the ways it does. In other words, the structural relations that an object and its constituents enter into can influence the causal powers that it manifests at any given time.⁸⁰ Chemical enantiomers behave identically in symmetric environments. But it is only when in asymmetric environments can we bear witness to their different causal powers.

⁷⁹ This image is of an unmodified photograph taken by David Benbennick on March 14, 2005. The image is licensed under the GNU Free Documentation License, version 1.2 (<https://gnu.org/licenses/fdl.html>), the Creative Commons Attribution-Share Alike 3.0 Unported License (<http://creativecommons.org/licenses/by-sa/3.0/deed.en>), and the Creative Commons Attribution-Share Alike 2.0 Generic License (<http://creativecommons.org/licenses/by-sa/2.0/deed.en>). Neither the licensors and nor the original author necessarily endorse the views expressed in this dissertation.

⁸⁰ Symons (2002) gives a nice thought experiment to illustrate how structural differences can influence causal outcomes. His example, however, relies crucially on the idea that the causal relation be construed probabilistically. I wish to remain neutral on this topic for this essay.

4.7 CONCLUDING REMARKS ON NATURALNESS

The account of kinds I've been discussing has addressed what Hawley and Bird (2011) call the "kindhood question", which addresses the question of what natural kinds are ontologically speaking. In this essay I've argued for the claim that natural kinds can be construed as complex structural properties, and I've made the case that certain chemical kinds, i.e. chemical isomers, that have posed difficulties for this sort of account before can in fact be accommodated. Moreover, the case of chemical isomers illustrates the idea that natural kinds involve the important element of causal structure, that is, the properties attributed to natural kinds are nomically linked to other properties, and that this causal structure is itself also constitutive of the kinds. If right, the account would give an answer to the "kindhood question" and give a reply to the *extensionality* objection from the beginning of the essay.

However, the discussion has said little about what Hawley and Bird call, the "naturalness question", which addresses the question of what distinguishes a natural kind from one that is non-natural. Hawley and Bird also observe that answering the naturalness question has occupied a large portion of the natural kinds literature, while the ontological question has gotten shorter shrift. I will not go into the details for why the account I've discussed here may also serve to answer the naturalness question, but the general idea is that the causal facts will play the role in distinguishing the class of natural from non-natural kinds. A kind with an arbitrary class of objects will lack the causal structure that natural kinds have. Fortunately, I am not alone in thinking this way, as others have made the case that causal factors are important for drawing the natural/non-natural distinction. What's more, this thought comes not from just traditional metaphysics, but from within philosophy of science as well. Khaldi (2013) for example argues that natural kinds are 'nodes in causal networks', where according to his account what

distinguishes 'real' kinds from non-natural kinds is that the former are associated with properties that are causally linked to other properties associated with those kinds. While it's clear that more work remains to be done, I take this sort of convergence from different philosophical perspectives to suggest that this view is on the right track.

5. CONCLUSION & PATHS FOR FUTURE WORK

5.1 CONCLUSION

The account of kinds explored in this thesis was an attempt to construe natural kinds as complex, causally structured properties, which drew inspiration from the theories of David Armstrong and Sydney Shoemaker. In Essay 1 I gave an overview of the famous semantic argument now known as the Slingshot, and I discussed several well-known deployments of that argument from the philosophical literature. I claimed that many of these arguments, particularly the ones that purport to deliver shocking metaphysical conclusions, must rely on several highly methodologically suspect strategies to do so. This was true also for the common noun version of the argument, which suffered from what I called the Extensional Malfunction. If these criticisms are right, this undercuts what might otherwise have appeared as a strong argument in favor of the view that natural kinds are simply classes of individuals.

In Essay 2, I offered a defense of David Armstrong's theory of structural universals against several prominent objections from David Lewis. The most serious of Lewis's objections I claimed were those that charged the incoherency of the very notion of a structural universal. I highlighted some relevant differences between Armstrong's characterization and that of Lewis's, noting that Armstrong's definition explicitly makes use of states of affairs. I then examined Katherine Hawley's assessment of the debate, and I argued that Hawley's interpretation of Lewis, the view that traces the problem back to Composition as Identity, does not explain why Lewis thought that non-unique composition is incoherent. I then showed how Lewis's arguments against Armstrong's structural universals implicitly relied on Humean Supervenience, and I argued that this is a question-begging move. This opened up the door for structural properties to play a bigger role in the final essay.

Essay 3 examined in more detail the objection from Essay 2 called the Isomer Problem, and sketched a view of natural kinds that appeals to Sydney Shoemaker's causal theory of properties. I argued against what I called the Simple Constitutive theory of kinds, which held that all of a complex chemical kind's constituents can be read off from its molecular formula, and I examined a strategy from Pagès to escape the objection from the Uniqueness of Composition by positing more complex structural relations for structural isomers. I then turned to the problematic case of chemical enantiomers, observing that the previous strategy for structural isomers was inadequate. What differentiates chemical enantiomers I claimed was a causal difference and I gave criteria for distinguishing them from one another in terms of their causal structure. Finally, I used Shoemaker's causal theory of properties to elucidate the notion of causal structure for natural kinds where I made use of his idea of a conditional causal power. I then used that idea to make sense of the structural conditions under which enantiomers will manifest their causal powers.

As I discussed in the introduction a number of topics once thought to be the sole domain of metaphysics have become of increasing interest to philosophers of science. This account has taken the notion of causation and given it a central place in individuating kinds. If the arguments I have made are on the right track, the account of natural kinds discussed here has the potential to be both metaphysically informative and scientifically accommodating. Moreover, the account would have the theoretical benefit of giving an account of natural kinds without appealing to a separate *sui generis* category of *kind*. While the arguments offered here certainly do not establish that this account can be generalized for all natural kinds, what they suggest is an account of natural kinds with promising potential. In closing I want to briefly discuss avenues for future work that this account opens up.

5.2 Future Work

Kind Membership. The main question addressed in this dissertation has been to discuss an answer to the question of what natural kinds are, metaphysically speaking. A related question however addresses the question of kinds and the principles that out to be employed for determining their members. That is, under what circumstances does a particular object count as a member of a certain natural kind? Moreover, how can such an account, assuming one is available, accommodate the apparent vagueness associated with the relationship of *membership*?⁸¹

Kind Essentialism. Debates about the essential nature of kinds arise in part from examples like the following: Necessarily, water is H₂O. However, evidence from the biological sciences suggests that the phenomenon of *polymorphism* (that some stable populations of a species display great phenotypic variety) shows that the view that all members of a species possess some essence is untenable. This subpart aims to understand what theses comprise those that go under the heading of ‘natural kind essentialism’, and to develop the claim that certain causal notions are in some sense essential to natural kinds.

Natural Kind Terms Reconsidered. We began with the semantic question of what natural kind terms refer to, which led us to ask the metaphysical question of what natural kinds are. The arguments offered here give us a potential answer to that question, that natural kinds are complex causal structured properties. However, what implications does this view have for the semantics of natural kind terms, particularly the Millian view that natural kind terms contribute only their referent to the sentences in which they occur?

⁸¹ Hawley and Bird (2011) suggest taking a supervaluationist strategy to the problem of vague kind membership, where some statements of kind membership simply lack a truth-value. Carlson (1999) considers the strategy of domain restriction for generic sentences, but ultimately casts doubt on its viability.

6. APPENDIX A: NOTES ON CLASSICAL MEREOLGY

The following is a brief overview of the various mereological symbols and their characteristics used in the body of the essay. I also demonstrate how all of the symbols may be derived from a single primitive operation. This section follows very closely the first chapter from Koslicki (2008), which in turn follows closely Simons (1987, Ch. 1).

Proper Part: $x < y$ “x is a proper part of y”

Characteristics:

Transitivity: $(x < y \ \& \ y < z) \supset (x < z)$, “If something is a proper part of another, and the second object is a proper part of a third, then the first object is a proper part of the third.

Asymmetry: $(x < y) \supset \sim(y < x)$, “If some one thing is a proper part of another, then the second thing is not a proper part of the first.”

Irreflexivity: $\sim(x < x)$, “Nothing is a proper part of itself.”

The proper part relation is perhaps the most intuitive since there are countless examples that come to mind – the ‘a’-key is a part of my laptop, my finger is a part of my hand, the city of St. Louis is a proper part of the state of Missouri, this appendix is a part of the larger essay, et cetera.

Proper or Improper Part: $x \leq y$ “x is a proper or improper part of y”

Characteristics:

Transitivity: $[(x \leq y) \ \& \ (y \leq z)] \supset (x \leq z)$

Non-Symmetry: $(\exists x)(\exists y)(x \leq y \ \& \ y \leq x) \ \& \ (\exists x)(\exists y) (x \leq y \ \& \ \sim y \leq x)$, “If something is a proper or improper part of another, then sometimes the second is a proper

or improper part of the first, and sometimes the second is not a proper or improper part of the first.”

Reflexivity: $x \leq x$, “any object is a proper or improper part of itself.”

If we assume identity and the proper part relation, we can think of the notion of proper or improper part via these assumptions – x is a proper or improper part of y whenever x is either a proper part of y or x is identical to y .

Overlap: $x \circ y$ “ x overlaps y ”

Characteristics:

Reflexivity: $x \circ y$, “every object overlaps itself”

Symmetry: $(x \circ y) \supset (y \circ x)$, “If an object overlaps another object, then the second overlaps the first.”

Intransitivity: $\sim[(x \circ y \ \& \ y \circ x) \supset (x \circ z)]$, “It’s not the case that if an object overlaps a second object, and the second object overlaps a third, that the first overlaps the third.”

If we begin with proper or improper parthood, two objects overlap if and only if they have a proper or improper part in common. Overlap and disjointness are closely related, as one can state that two objects overlap if and only if they are not disjoint.

Disjointness: $x \not\mid y$ “ x is disjoint from y ”

Characteristics:

Symmetry: $(x \not\mid y) \supset (y \not\mid x)$, “If an object is disjoint from another object, then the second is disjoint from the first.”

Irreflexivity: $\sim(x \not\mid x)$, “Nothing is disjoint from itself.”

Intransitivity: $\sim[(x|y \ \& \ y|z) \supset (x|z)]$, “It’s not the case that if an object is disjoint from a second, and the second is disjoint from a third, that the first object is disjoint from the third.

Two objects are disjoint if and only if they do not overlap, that is they do not share a proper or improper part in common. The next seven things in the list are all *singular terms*, as one may gather from the occurrence of the definite article within the quotation marks.

Binary Product: $x \bullet y$ “the produce of x and y”

The *binary product* of x and y is the individual that is a part of both x and y, and which is such that any common part of x and y is also part of it. This is the mereological analogue to the set-theoretical notion of *intersection*, with the notable exception that the null set is will always be the intersection of two disjoint sets. Most mereologists will renounce the notion of the null object, defined as the thing that is a part of everything.

Binary Sum: $x + y$ “the sum of x and y”

The *binary sum* is the mereological analogue of set theoretical *union*, and is the object, which is such that there is something that overlaps it if and only if it overlaps either x or y. Simons (1987, p. 14) suggests that a broom is approximately the sum of its handle and its head.

Difference: $x - y$ “the difference of x and y”

The *difference* of x and y is the largest object contained in x, which has no part in common with y and exists only if x is not a part of y. Furthermore, if x and y overlap and x is not a part of y, then $x - y$ is a proper part of x.

General Sum (Fusion): $\sigma x[F(x)]$ “the sum (fusion) of all x’s that are F”

The *General Sum* or *Fusion* guarantees that every class of individuals has a sum, and hence is related the principle of Unrestricted Composition. The *fusion* of a class of objects satisfying a certain predicate F via the variable-binding operator, ‘ σ ’, is denoted by “ $\sigma x[F(x)]$ ”.

Product (Nucleus): $\pi x[F(x)]$ “The product (nucleus) of all
x’s that are F”

Similar to general sum, the *Product* or *Nucleus* of a class of objects satisfying a given predicate ‘ π ’ all of whom overlap, that is share a common part is denote by “ $\pi x[F(x)]$ ”.

The Universe: U “The Universe”

Since we’ve introduced general sum or fusions that allow for arbitrary sums, then there must be a sum of all objects. This individual will be unique and every object will be a part of it. One might think that, by analogy with the empty set, there could be something like the empty Universe. This is misguided, as the Universe simply is the sum of everything that exists. So on the supposition that no things exists, then neither would the Universe.

Complement: $U - x$ “The complement of x”

Having already presented *differences* and the Universe, for every individual there is a unique individual consisting of the rest of the Universe. In this respect, the complement is simply the difference between a given individual and the Universe.

Atom: $At(x)$ “x is an atom”

Unlike the previous seven mereological concepts that dealt with singular terms, “ $At(x)$ ” denotes a predicate, namely that something is an atom. An atom is an individual that has no proper parts, and is hence, as the name suggests, indivisible. One shouldn’t confuse this mereological notion of atom with that discussed in physics, which as we all know, are themselves composed of numerous proper parts.

I now wish to show how to derive all mereological operations from a single primitive. For my purposes, I'll start with overlap since I mentioned it in discussion of Koslicki's criticism of David Lewis' *Vagueness Argument*. I'll assume first-order predicate-logic, identity, set theory, and the following characteristics of *overlap*, "x o y": reflexivity, symmetry, and intransitivity. From here *disjointness* may be defined by the negation of overlap:

$$\underline{\text{Disjointness:}} \quad x \uparrow y \equiv_{\text{def}} \sim(x \circ y)$$

From here we can define the remaining mereological relations as follows:

$$\underline{\text{Parthood:}} \quad x \leq y \equiv_{\text{def}} (\forall z)(z \uparrow y \supset z \uparrow x)$$

$$\underline{\text{Proper Part:}} \quad x < y \equiv_{\text{def}} (x \leq y \ \& \ x \neq y)$$

$$\underline{\text{Sum (Fusion):}} \quad x \text{Fu} \alpha \equiv_{\text{def}} (\forall z)[(z \uparrow x) \equiv (\forall y)(y \in \alpha \supset z \uparrow y)]$$

$$\underline{\text{Product (Nucleus):}} \quad x \text{Nu} \alpha \equiv_{\text{def}} (\forall z)[(z \leq x) \equiv (\forall y)(y \in \alpha \supset z \leq y)]$$

The definition of (proper or improper) parthood states that an object is a *part* of another if and only if anything disjoint from the second object is disjoint from the first. An object is a *proper part* of another object if and only if the first is a proper or improper part of the second and these two are not identical. An object is the *sum* of a set, α , if and only if everything discrete from the sum is discrete from every member of the set and vice versa. Something is the *product* of a set, α , if and only if everything that is a proper or improper part of the product is a proper or improper part of every other member of the set and vice versa. The remaining mereological concepts, *binary sum*, *difference*, *product*, *universe*, and *complement* can also be defined in similar ways. For brevity I direct the interested reader to Simons (1987, Ch. 2).

We can now more formally state the three characteristic axioms of mereology, as construed in Leonard and Goodman's *Calculus of Individuals*, which assuming any axioms sufficient for first-order predicate-logic with identity and set theory, are as follows:

Axiom 1(Fusions): $(\exists x)(x \in \alpha) \supset (\exists y)(yFu\alpha)$

Axiom 2(Parthood): $(x \leq y \ \& \ y \leq x) \supset (x = y)$

Axiom 3(Overlap): $(x \circ y) \equiv \sim(x \uparrow y)$

The first axiom is the controversial principle of Unrestricted Composition, which establishes the existence of fusions and the second axiom establishes the uniqueness of those fusions. The third axiom merely establishes the formal characteristics of overlap with respect to disjointness.

Alternatively, one may provide a gradual articulation of the full theory by beginning with a single primitive operation, as demonstrated above, followed by definitions of all the other mereological operations. Then, the axioms required for CEM are as follows.

Axiom1*: Any axiom set sufficient for first-order predicate logic with identity.

Axiom2*(Asymmetry): $(x < y) \supset \sim(y < x)$

Axiom3*(Transitivity): $[(x \leq y) \ \& \ (y \leq z)] \supset (x \leq z)$

Axiom4*(WSP): $(x < y) \supset (\exists z)(z < y \ \& \ z \uparrow x)$

At this there is a gradual articulation of stronger and stronger axioms to supplement axioms one through three, eventually stating the following “General Sum Principle” (GSP), which when added to the four axioms above, results in a system with the strength of full-fledged Classical Extensional Mereology:

General Sum Principle: $(\exists x)(F(x)) \supset (\exists x)(\forall y)((y \circ x) \equiv (\exists z)(F(z)) \ \& \ (y \circ z)))$

GSP states that for any objects that satisfy a given predicate F , there is a sum of those objects (on the condition that the predicate’s extension is non-empty. While there are several intermediate states as the theory is gradually stated, GSP subsumes all the previous axioms, and so combined with the above four axioms reaches the full strength of the system.

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