The Varieties of Constitutive Explanation*

Benjamin Brast-McKie

September 13, 2022

Abstract

Constitutive explanations play important roles throughout many domains of inquiry. What is necessary for an atom to be gold? What is sufficient for an action to be wrong? What is it for a number to be prime? These are good question with good answers. Instead of defending any particular constitutive explanations, this paper provides an account of constitutive explanatory readings of 'necessary for', 'sufficient for', and 'what it is for', arguing that modal regimentations of these locutions fail to track the explanatory relationships that these locutions are typically intended to express. Rather, I will present a logic for constitutive explanation which includes modal and extensional operators. In support of these developments, the majority of the paper will be devoted to clarifying the theoretical roles which the different forms of constitutive explanation play, as well as comparing the present treatment to related accounts.

A common understanding of English affords all of the resources needed to express constitutive explanations of a variety of different forms. For instance, consider the following examples from chemistry, ethics, and mathematics:

(G) Having 79 protons is *necessary for* an atom to be gold.

(W) Harming only for fun is *sufficient for* an action to be wrong.

(P) Having exactly two divisors is *what it is for* a number to be prime.

In general, constitutive explanations aim to specify the nature of the things around us, where given any property whatsoever, one may ask what it is for something

*I am grateful to Mathias Böhm, Kit Fine, John Hawthorne, Michail Peramatzis, and Tim Williamson for extensive comments and discussion on previous versions of this paper.

to have that property. Whereas `(P)` provides a complete account of what it is for a number to be prime, `(G)` and `(W)` do not provide complete accounts of what it is for an atom to be gold, or for an action to be wrong. Although having 79 protons is necessary for an atom to be gold, having 79 protons is not what it is for an atom to be gold, since a ball of 79 protons is not gold. Similarly, even if it is assumed that harming only for fun is sufficient for an action to be wrong, one might admit that there are other ways for an action to be wrong, and so harming only for fun is not what it is for an action to be wrong. Despite failing to provide complete accounts, `(G)` and `(W)` nevertheless succeed in providing partial accounts of what it is for an atom to be gold, and what it is for an action to be wrong. It is the ambition of this paper to provide a theory of constitutive explanation which describes the relationships that the different forms of constitutive explanation bear to each other along with a framework for reasoning with constitutive explanatory terms.

The paper will be structured as follows: §1 identifies a theoretical target which an adequate theory of constitutive explanation may aim to capture by considering properties that constitutive explanations share in common, as well as properties which distinguish the different forms of constitutive explanation; §2 presents arguments against intensionalist theories of constitutive explanation which identify necessarily equivalent propositions, highlighting the distinctive advantages of the present approach; §§3 – 4 will then contrast a number of related theories of essence and ground that have been defended in the literature; and §5 concludes by presenting a logic for constitutive explanation (CE) which provides an intuitive framework for reasoning with constitutive explanatory terms. Whereas I provide a state semantics and theory of logical consequence over which CE may be shown to be sound in Brast-McKie (draft), the present paper will focus on providing motivation for adopting CE given the theoretical roles that the varieties of constitutive explanation will be found to play.

1 Theoretical Roles

Since it is often difficult to say what it is for something to be the case, it is common to make claims about *part of what it is* for something to be the case. For instance, instead of saying what it is for an atom to be gold, `(G)` makes a claim about part of what it is for an atom to be gold. Put otherwise, `(G)` asserts what is *essential* for an atom to be gold while falling short of saying all of what is essential for an atom to be gold. In particular, having 79 neutrons is also essential for an atom to be gold, where something similar may be said for the various bonding relationships that are essential for such entities to form a gold atom. Instead of attempting to explain what it is for something to be the case all at once, one may make progress towards answering such difficult questions by asking what is necessary for something to be the case and systematically surveying the space of correct answers.

Even in asking what is necessary for something to be the case, it is sometimes impossible to provide adequate answers. For instance, one may struggle to say what is necessary for an action to be wrong. Instead of seeking to identify any part of what it is for something to be the case, one might describe the different *ways* for something to be the case. Whereas `(W)` indicates one way for an action to be wrong, one might claim that acting selfishly is also a way for an action to be wrong without claiming that either way is part of what it is for an action to be wrong. Put otherwise, `(W)` indicates a *ground* for the wrongness of an action, where acting selfishly may be taken to provide a distinct ground. In many cases, the different grounds are incompatible, and so none are essential. For instance, although being entirely crimson is a way for something to be entirely red, and being entirely scarlet is also a way for something to be entirely red, nothing is entirely crimson and entirely scarlet. Accordingly, neither being entirely crimson nor being entirely scarlet are part of what it is for something to be entirely red. Put otherwise, being entirely crimson and being entirely scarlet are both sufficient for being entirely red, but neither is necessary for being entirely red.

In the special circumstance where enough necessary conditions have been identified to be jointly sufficient for a given condition, one may assert the stronger claim that the conjunction of those conditions provide an account of *what it is* for the condition in question to be the case. More precisely, we may assert the following where 'A' and 'B' range over sentences:

Reduction: For it to be the case that A is what it is for it to be the case that B if and only if for it to be the case that A is both necessary and sufficient for it to be the case that B.[1]

For instance, having exactly two divisors is both necessary and sufficient for a number to be prime, and so given *Reduction*, having exactly two divisors is what it is for a number to be prime. By contrast, having 79 protons is necessary but insufficient for an atom to be gold, and harming only for fun is sufficient but not necessary for an action to be wrong. Thus it follows by *Reduction* that having 79 protons is not what it is for an atom to be gold, nor is harming only for fun what it is for an action to be wrong.

In order to further characterise the theoretical roles which the different forms of constitutive explanation play, it will help to consider the direction of explanation from the explanans to the explanandum. For instance, whereas having 79 protons provides a partial account of what it is for an atom to be gold, being gold does not provide either a partial or full account of what it is for an atom to have 79 protons. Similarly, although harming only for fun provides a partial account of why an action is wrong, being wrong does not provide a partial or full account of why an action harms only for fun. Or perhaps most vividly of all, having exactly two divisors provides a complete account of what it is for a number to be prime, but being prime does not provide a complete account of what it is for a number

[1] See Fine (2015, p. 307) for a related suggestion.

to have exactly two divisors. In each of these cases, the explanans indicates some more fundamental aspect or layer of the nature of the explanandum. Whereas 'sufficient for' can be used to express the different ways for the explanandum to obtain, 'necessary for' indicates the different parts of what is required for the explanandum to obtain. Given *Reduction*, 'what it is for'-claims indicate a way for the explanandum to obtain which is required for the explanandum to obtain. Setting these differences aside, constitutive explanations are typically asymmetric. In particular, most 'what it is for'-claims yield exceptions to the following principle:

Reduction Symmetry: If for it to be the case that A is what it is for it to be the case that B, then for it to be the case that B is what it is for it to be the case that A.

To take another example, we may observe that although being H_2O is what it is for something to be water, being water is not what it is for something to be H_2O.[2] As the following section will bring out, failures of *Reduction Symmetry* motivate the development of a hyperintensional logic for constitutive explanation which distinguishes necessarily equivalent propositions.

Before arguing that the constitutive explanatory operators are sensitive to hyperintensional differences, it will help to consider the interaction between the constitutive explanatory operators and the metaphysical modal operators. For instance, `(G)`, `(W)`, and `(P)` each entail necessary connections which hold between their explanans and explanandum. In particular, it follows from `(G)` that it is necessary that if an atom is gold, then the atom has 79 protons, or given `(W)`, it is necessary that if an action harms only for fun, then the action is wrong. Additionally, it follows from `(P)` that it is necessary that a number is prime if and only if that number has exactly two divisors. Generalising on these examples, we may observe the following patterns in reasoning:

[2] Alternatively, one may consider what it is to contain H_2O at 72° F and 1 bar of pressure.

Implication: (E) If for it to be the case that A is necessary for it to be the case that B, then it is necessary that A if B.

(G) If for it to be the case that A is sufficient for it to be the case that B, then it is necessary that A only if B.

(R) If for it to be the case that A is what it is for it to be the case that B, then it is necessary that A if and only if B.

In the principles above, I will take 'it is necessary that' to express metaphysical necessity, where metaphysical necessity concerns all objective possibilities whatsoever.[3] Given *Implication*, it follows from `(G)` and `(W)` respectively that there are no objective possibilities where an atom is gold without having 79 protons, or where an action harms only for fun without being wrong. Similarly, it follows from `(P)` that there are no objective possibilities where a number is prime without having exactly two divisors, or where a number has exactly two divisors without being prime. Rather than excluding objective possibilities from the space of possibilities over which the metaphysical modal operators quantify, constitutive explanations describe the limits of what is objectively possible even on the broadest understanding of objective possibility.

Although identifying necessary connections is often an important first step in interrogating a given subject-matter, it is typically the underlying explanatory connections which are of primary interest. For instance, in asking what is necessary for an atom to be gold, one asks not just about the possibilities in which an atom is gold, but rather about the nature of gold along with all that is required for an atom to be gold. Something similar may be said in asking what is sufficient for an action to be wrong, or in asking what it is for a number to be prime, and so on for

[3] For definiteness, I will follow Williamson (2016, p. 455) in taking metaphysical modality to be the strongest objective modality so that, "a proposition is *metaphysically possible* if and only if it has at least one sort of objective possibility," and "*metaphysically necessary* if and only if its negation is not metaphysically possible, that is, if and only if it has every sort of objective necessity," though nothing below turns on this assumption.

other case. In raising these inquiries, it is natural to expect the explanans to be wholly relevant to its explanandum. Additionally, I will understand relevance in terms of partial subject-matter as follows:

Relevance: It being the case that A is wholly relevant to it being the case that B if and only if the subject-matter of it being the case that A is part of the subject-matter of it being the case that B.

I will take the subject-matter of a proposition to be what that proposition is about, where this may be taken to include all of the different ways for that proposition to be true.[4] For instance, the subject-matter of Jill's action being wrong includes all of the different ways for Jill's action to be wrong, where the subject-matter of Jill's action harming only for fun includes a select range of the ways for Jill's action to be wrong, i.e., those ways in which her action harms only for fun. Accordingly, the subject-matter of Jill's action harming only for fun is *part* of the subject-matter of Jill's action being wrong. Although I provide a more detailed account of subject-matter in Brast-McKie (2021), it will suffice for present purposes to rely on this limited picture of subject-matter and the various parthood relationships that subject-matters bear to each other. In particular, I will assume that in any true constitutive explanation, the explanans must be wholly relevant to its explanandum insofar as what the explanans is about must be part of what the explanandum is about.

In addition to bearing a necessary connection to a given explanandum while also being wholly relevant to that explanandum, constitutive explanations concern *things being certain ways* independent of the means by which we represent those things, or those ways of being. For instance, in asking what it is for Hesperus

[4] Letting interpreted sentences inherit the subject-matter of the propositions that they express, it is is important to distinguish the subject-matter of a sentence from the *subject* of that sentence. For instance, although 'Sam woke up' and 'Sam won the race' both concern Sam as the subject of these sentences, the former is about Sam's state of consciousness, whereas the latter is about Sam's athletic achievements.

to be rising, one asks about the relative position of astral bodies independent of which representational devices happen to have been employed in asking the question. Accordingly, one may ask the very same question by asking what it is for Phosphorus to be rising, since for Hesperus to be rising just is for Phosphorus to be rising. More generally, constitutive explanatory locutions are insensitive to differences in guise insofar as their arguments admit the free substitution of co-referring expressions without effecting the explanation which is thereby expressed.[5] Put otherwise, constitutive explanatory locutions are transparent operators, where transparency is defined:

Transparency: An n-place sentential operator $\mathcal{Q}$ is transparent if and only if for it to be the case that $\mathcal{Q}(A_1, \ldots, A_n)$ just is for it to be the case that $\mathcal{Q}(B_1, \ldots, B_n)$ whenever for it to be the case that A_i just is for it to be the case that B_i for all $1 \leqslant i \leqslant n$.

The definition above makes essential use of the locution 'just is for' which I will take to express propositional identity. Specifically, I will take claims of the form ⌜For it to be the case that A just is for it to be the case that B⌝ to be true just in case ⌜A⌝ and ⌜B⌝ express the same "way for things to be" which it will be convenient to refer to as a proposition.[6] Although it may often be controversial which sentences express the same proposition, we may nevertheless look to *Transparency* in order to specify what it is for an operator to be insensitive to guise. Accordingly, I will take constitutive explanations to be expressed by transparent operators, where in particular, 'necessary for', 'sufficient for', and 'what it is for' all satisfy this requirement.

Generalising on the observations above, I will assume that constitutive explana-

[5] If one prefers to restrict talk of reference to expressions of type e, then we must find another word such as 'co-expressing', and so on for all other grammatical types.

[6] Since propositional identity claims of the indicated form do not make any reference to propositions, one need not admit an ontology of propositions over which first-order quantifiers range in order to assert propositional identity claims. See §3 for further discussion.

tions are typically asymmetric and expressed by transparent two-place sentential operators where the explanans is wholly relevant to its explanandum, while bearing a necessary connection to its explanandum. Despite satisfying this broad characterisation, we may distinguish between the types of constitutive explanation of which `(G)`, `(W)`, and `(P)` are instances by considering the different necessary connections which they each entail. In particular, I will assume that 'necessary for'-claims express *essence explanations* where the explanans is strictly entailed by the explanandum, and that 'sufficient for'-claims express *grounding explanations* where the explanans strictly entails the explanandum. Additionally, I will take 'what it is for'-claims to express *reduction explanations* where, given *Reduction*, the explanans is both necessary and sufficient for the explanandum, and so necessarily equivalent to the explanandum. Although convenient, this taxonomy does little to provide an account of the nature of these different forms of constitutive explanation. Rather, §5 will present a logic for constitutive explanation (CE) which aims to describe the space of exceptionless principles for reasoning with constitutive explanatory language. In anticipation of these developments, the follow section will present arguments against purely intensional accounts of what 'necessary for', 'sufficient for', and 'what it is for' express in contexts such as `(G)`, `(W)`, and `(P)`, respectively.

2 Against Intensionalism

Consider a utilitarian who claims that maximising utility is what it is for an action to be wrong. For simplicity, it will be convenient to focus on a particular action rather than all actions. For instance, consider the following claims:

`(U)` Maximising utility is *what it is for* Sam's action to be right.

`(#U)` Being right is *what it is for* Sam's action to maximise utility.

In addition to defending claims such as `(U)`, it is natural to expect utilitarians to reject their converses such as `(#U)`. Were one to maintain both `(U)` and `(#U)`, one might claim that the occurrences of 'what it is for' express propositional identity, where propositional identity is of course a paragon of symmetry. On such a view, both `(U)` and `(#U)` assert that the sentences 'Sam's action is right' and 'Sam's action maximises utility' express the very same proposition by different means. By contrast, I will be concerned to elaborate a non-symmetric reading of 'what it is for', thereby providing an account of what I take to be the natural direction of explanation witnessed by such examples as `(U)` and `(P)` as opposed to their converses.[7] Nevertheless, it is important to emphasise that instead of asserting or rejecting any particular reduction claims, the present account is designed to accommodate asymmetries in reduction while remaining neutral about the truth-value of particular examples.

Assuming that there are some true 'what it is for'-claims whose converses do not hold, it follows from *Reduction* that 'necessary for' and 'sufficient for' do not express each other's converse. For example, suppose that one were to accept `(U)` while rejecting `(#U)`. Given *Reduction*, maximising utility is both necessary and sufficient for Sam's action to be right. If 'necessary for' and 'sufficient for' expressed each other's converses, then being right would be necessary and sufficient for Sam's action to maximise utility, where `(#U)` would follow by another instance of *Reduction*. Insofar as there are true 'what it is for'-claims whose converses do not hold, it follows from *Reduction* that 'necessary for' and 'sufficient for' do not express each other's converse.[8] The same conclusion can also be drawn from the assumption that for any true constitutive explanation, the explanans must

[7] Although one could take 'is for' to express reduction instead of 'what it is for', looking to the order of the arguments to encode the order in explanation, I will take 'is for' to be ambiguous between reduction explanations and propositional identity claims.

[8] Fine (2015, p. 306-7) claims that constitutive readings of 'necessary for' and 'sufficient for' do not express each other's converse since the explanans of each is determinative of its explanandum. Fine does not, however, provide an account of determination.

be wholly relevant to its explanandum, though the explanandum may fail to be wholly relevant to its explanans. Specifically, it follows from *Relevance* that if a constitutive explanatory reading of 'necessary for' and 'sufficient for' expressed each other's converse, then the explanans and explanandum for each locution would have to be wholly relevant to each other, though this often fails to be the case. For instance, assuming that there are many ways for an action to be wrong besides harming only for fun, the subject-matter of an action being wrong will include more than the subject-matter of an action harming only for fun, and so being wrong fails to be wholly relevant to an action harming only for fun. It follows more generally that constitutive explanatory readings of 'sufficient for' and 'necessary for' do not express each other's converse.

Given that constitutive readings of 'sufficient for' and 'necessary for' do not express each other's converse, it follows in particular that these locutions do not express strict implication and its converse as one might have otherwise assumed given an intensional theory of propositions. Moreover, we may show that admitting exceptions to *Reduction Symmetry* raises general problems for intensional theories of propositions, at least given a number of plausible assumptions. To begin with, consider the following principles:

Intensionalism: If it is necessary that A if and only if B, then for it to be the case that A just is for it to be the case that B.

Identity Symmetry: If for it to be the case that A just is for it to be the case that B, then for it to be the case that B just is for it to be the case that A.

Whereas *Intensionalism* makes necessary equivalence a criterion of propositional identity— a premise that I will provide reason to reject— *Identity Symmetry* asserts the uncontroversial claim that propositional identity is symmetric. Given these principles, we may derive a contradiction by classical reasoning from any exception to *Reduction Symmetry.* For definiteness, I will assume `(U)` on behalf of the utilitarian while rejecting `(#U)`, reasoning as follows:

`(1)` It is necessary that Sam's action maximises utility if and only if his action is right.

`(2)` For Sam's action to maximise utility just is for his action to be right.

`(3)` For Sam's action to be right just is for his action to maximise utility.

`(4)` Being right is what it is for Sam's action to be right.

Observe that `(1)` follows from `(U)` by *Implication* (R), `(2)` follows from `(1)` by *Intensionalism*, and `(3)` follows from `(2)` by *Symmetry.* Additionally, `(4)` follows from `(U)` and `(2)` by the transparency of a constitutive explanatory reading of 'what it is for', where `(#U)` follows from `(4)` and `(3)` for the same reason.[9] Intuitively, these final two steps are the result of freely substituting co-referring sentences in `(U)` given the propositional identities stated in `(2)` and `(3)`. Since the argument began by rejecting `(#U)`, we find good reason to give up one of the assumptions which figured in the reasoning above. Rather than adopting a symmetric reading of 'what it is for', or else giving up the transparency of the intended constitutive reading of 'what it is for', I will reject *Intensionalism.* Thus there are necessarily equivalent propositions which are not identical, thereby motivating a hyperintensional theory of propositions which distinguishes necessarily equivalent propositions.

Although it is not the ambition of the present paper to survey intensional theories of what 'necessary for', 'sufficient for', and 'what it is for' might be taken to express, it is nevertheless worth considering what is at stake in attempting to maintain *Intensionalism.* In particular, one may maintain *Intensionalism* while admitting exceptions to *Reduction Symmetry* by taking 'what it is for' to operate in part on the means by which the explanans and explanandum are each expressed,

[9] This argument may be shown to constitute a proof within CE which I present in §5.

making 'what it is for' a non-transparent operator, contrary to what was claimed above. However, at least for a wide range of cases, it appears that 'what it is for'-claims do not assert anything which depends upon the means of assertion. Diverging in yet another direction, an intensionalist may maintain transparency by taking 'what it is for' to express propositional identity which is of course symmetric and none other than necessary equivalence given intensionalism. Accordingly, such an account cannot accommodate the apparent direction in explanation of 'what it is for'-claims without some addition. In particular, one might look to pragmatics in order to account for the infelicity of asserting a 'what it is for'-claim along with its converse, while taking 'what it is for' to express propositional identity. By contrast, I will maintain both the transparency as well as non-symmetry of 'what it is for'. It follows that `(U)` may be taken to be true while its converse `(#U)` may be taken to be false rather than merely infelicitous.

In rejecting intensional theories of propositions, it remains to provide an alternative hyperintensional theory of propositions. Whereas I provide such an account in Brast-McKie (2021), the present paper will be devoted to developing hyperintensional readings of 'necessary for', 'sufficient for', and 'what it is for' which respect the theoretical roles that these locutions have so far been found to play. Rather than continuing to articulate intuitively valid principles for the varieties of constitutive explanation that can be expressed in English, §5 will stipulate how to reason with essence, grounding, and reduction operators, where these artificial notions have been explicitly designed to regiment constitutive readings of 'necessary for', 'sufficient for', and 'what it is for', respectively. In anticipation of these developments, the following two sections will criticise a number of related theories of essence and grounding that have been developed.

3 Theories of Ground

In a recent paper, Dasgupta (2017) confesses to no longer understanding what theories of grounding are about. Indeed, the literature on grounding has come to include a wide array of different notions which diverge not only in which principles they are said to obey, or the theoretical roles they are taken to play, but even in their logical forms. Whereas Fine (2001) began his investigation into grounding by employing a two place sentential operator which he took to express an explanatory relation between truths, Schaffer (2009) took grounding to be a dependence relation between objects of any kind whatsoever, and Rosen (2010) took grounding to be a relation which only holds between facts. Despite their different extensions, these latter relations are expressed by two-place predicates rather than sentential operators, though Schaffer (2012, 2015) went on to defend a four-place predicate for which he adopts the contrastive reading 'x rather than x^* grounds y rather than y^*'. Diverging along yet another dimension, Fine (2012a,b) shifted to a many-one grounding operator which takes many antecedents and a single consequent as arguments, whereas Dasgupta (2014) and Litland (2016, 2018) consider a many-many grounding operator which accepts many antecedents and many consequents.

In addition to the different logical forms attributed to grounding, there is also a range of different interpretations which correspond to the distinct theoretical roles that grounding is taken to play. In particular, Fine (2012a) contrasts metaphysical readings of grounding claims with both natural and normative readings, arguing that each reading ought to be regimented by a distinct primitive which cannot be defined in terms of a single generic notion of grounding. Additionally, Correia (2008, 2010, 2014), Fine (2012a), Correia and Schnieder (2012), Correia and Skiles (2019), and Krämer and Roski (2015) contrast metaphysical readings of grounding claims with both logical and conceptual readings, resulting in a range of further theoretical targets at which a theory of grounding might aim. Even in settling on a logical form and intended interpretation for a primitive grounding term, one may consider a range of related notions that may be defined in terms of that primitive, further amplifying the number of grounding notions that one might consider.

Given this dizzying array of logical forms and interpretations which different theorists attribute to grounding, it is natural to sympathise with Dasgupta's complaints, asking how we are to make sense of grounding, if any sense can be made at all. However, instead of expressing concern for how many notions of grounding there appear to be, Dasgupta's (2017) focuses on the "inflationary" commitments that he takes grounding theorists to adopt, recommending a "deflationary" account which, "does not require that there are any such things as facts or propositions," (p. 79). Dasgupta does not, however, mention Correia's (2010, p. 254) observation that operational approaches to grounding are ontologically neutral in a manner which relational approaches are not. For instance, we may compare the ontological commitments of the claims which Correia adopts such as `(U)′` to the claims which Rosen maintains such as `(U)″`:

`(U)′` Sam's action is right *because* his action maximises utility.

`(U)″` The fact that Sam's action maximises utility *grounds* the fact that his action is right.

Suppose that one were to assume a Quinean account of ontology according to which ontology is the study of what there is, where this is restricted to the domain of objects over which the first-order quantifiers range. The ontological commitments of a sentence or theory may then be taken to include the objects that there must be in order for that sentence or theory to be true. Although claims such as `(U)″` are inflationary by Dasgupta's lights on account of their ontological commitment to facts where something similar may be said if both occurrences of 'fact' were to be replaced with 'proposition', `(U)′` is not committed to an ontology of either facts or propositions. Nevertheless, Correia speaks informally of propositions being true because of others, or of propositions grounding each other as a matter of convenience since officially he only needs to assert claims of the form ⌜B because A⌝ which do not include any general ontological commitments. Something similar may be said for the sentential operators 'necessary for', 'sufficient for', and 'what it is for', as well as the metaphysical modal and truth-functional operators.

Since any theory which takes grounding to be expressed by a sentential operator qualifies as deflationary by Dasgupta's lights, such considerations do little to narrow the space of theoretical targets at which a theory of grounding might reasonably aim.[10] By contrast, taking a common reading of 'because' to provide an informal understanding of grounding in a range of cases at least goes so far as to suggest a rough pre-theoretic target for a theory of grounding. However, not all uses of 'because' express grounding claims. For instance, it is also common to use 'because' to express causal claims. Accordingly, more must be said in order to specify the theoretical role which grounding is taken to play. In particular, one might seek to identify valid patterns in reasoning with the intended use of 'because' by evaluating which informal 'because'-claims hold in full generality on the intended reading. Despite relying on an informal understanding of 'because' in order to interpret grounding, Correia (2010) does not discuss the intended reading of 'because' which he intends, nor does he describe the theoretical role grounding might claim to play by motivating informal principles which a theory of grounding ought to capture. Although Correia specifies how he takes grounding to be understood by providing its logic, without also indicating a theoretical target for grounding there is no way to evaluate the adequacy of the proof system that he provides.

Like Correia, Dasgupta (2017, p. 75) relies on an informal understanding of 'because', however, goes on to emphasise that in opposition to the notions stipulated by philosophers, what he means by 'ground' is, "just a label for one sense of the

[10] Deflationists cannot, however, maintain relational theories of grounding.

English word 'because'," which he sets apart from causal readings of 'because' by way of the following example:

> `(Table)` Why is there a table here? One answer: Because someone put it there yesterday. Another answer: Because there are pieces of wood arranged table-wise. The former is called a causal explanation, the latter a constitutive explanation. 'Ground', as I use the term, is just a label for this latter sense of 'because'. (p. 75)

Although Dasgupta takes a constitutive reading of 'because' to be quotidian insofar as, "it is a concept of ordinary English that is also common-place in science," the example above does little to support this point. Instead of considering some pieces of wood arranged table-wise, dualism about mind, substantivalism about space, or any of the other thoroughly philosophical grounding claims that Dasgupta recounts, it is worth beginning with a genuinely quotidian case in support of the commonality of grounding claims:

> `(Teacup)` After knocking a teacup off the table, a child asks her parent, "Why did it break?" The parent responds, "Because it fell and hit the floor, and is very brittle." The child then asks, "Why is it brittle?"

It is easy to contemplate the parent's conundrum: presumably the child is not asking for a causal explanation of how it is that the teacup came to be brittle, but rather an explanation of what constitutes its brittleness. It is not difficult to drum up a host of similar examples since young children often ask about the constitution of their surroundings, inquiring not about the meaning of words, but rather about the nature of some salient property or other.[11]

Suppose that the parent in `(Teacup)` were to possess the requisite knowledge to answer the child's question, describing the nature of the polycrystalline structure of the ceramic teacup in detail. For simplicity, consider the following:

`(B)` The teacup is brittle *because* it has ceramic structure C.

[11] This is not to claim that children do not also inquire about the meanings of words, though I take it that this typically happens at a later stage of cognitive development.

Although Dasgupta introduces grounding as *a* constitutive reading of 'because', he goes on to write, "What I claim is quotidian is just the constitutive sense of 'because'," (p. 76) apparently taking grounding to be the *only* form of constitutive explanation. Even if Dasgupta were to give this up, admitting that grounding is but one among a range of constitutive readings of 'because', the examples which he goes on to provide nevertheless conflate the different forms of constitutive explanation which common sense English is able to articulate. For instance, Dasgupta also considers the following example:

`(H)` The water is hot *because* its mean kinetic energy is high.[12]

In taking `(H)` to be a grounding claim, Dasgupta overlooks an important difference between `(H)` and claims such as `(B)`: whereas there are other ways of being brittle besides having ceramic structure C, there is just one way of being hot. Thus although having high mean kinetic energy is what it is for the water to be hot, one cannot claim that what it is to be brittle is to have ceramic structure C given the existence of non-ceramic brittle materials such as high carbon steel. Even though `(B)` is naturally interpreted as a grounding claim and `(H)` is naturally interpreted as a reduction claim, this difference is hidden by using 'because' in both cases.[13]

Rather than taking either 'ground' or 'reduction' to be a label for a single constitutive reading of 'because', I will take 'because' to be a general explanatory term which admits of a number of different constitutive readings in addition to its non-constitutive readings.[14] For instance, consider the following claim:

`(G)`$'$ The atom is gold *because* it has 79 protons.

[12] Dasgupta (2017, p. 75) presents `(H)` in question/answer form.

[13] Given that 'because' is factive, one may either regiment `(B)` in terms of a factive notion of grounding— i.e., $A \leqslant_{\text{F}} B := (A \leqslant B) \wedge A$— or else take factivity to be an implication given by the pragmatics. For now, I will remain neutral on how factivity is to be understood.

[14] Schnieder (2011) provides a logic of 'because' in which $\ulcorner A \wedge B$ because $A\urcorner$ follows from $\ulcorner A\urcorner$. By contrast, the analogous principle for full grounding fails to hold. We may also note that whereas 'because' is naturally taken to be factive insofar as the truth of a 'because'-claim entails the truth of its antecedent and consequent, the same cannot be said for 'sufficient for', 'necessary for', and 'what it is for' on either constitutive or purely modal readings.

Even though `(G)′` does not provide a complete explanation of what it is to be gold, having 79 protons nevertheless bears an explanatory relationship to the atom being gold, where drawing any such explanatory relationship between truths is all that is required for a 'because'-claim to be true. By contrast, `(G)` asserts something much more specific, indicating the type of explanation at hand. For instance, 'necessary for' in `(G)` cannot be replaced with either 'sufficient for' or 'what it is for' while preserving the truth of the resulting claim, where similarly 'because' in `(B)` cannot be replaced with either 'necessary for' or 'what it is for' without making the resulting claim false. By speaking of, "the constitutive sense of 'because'," Dasgupta treats the variety of constitutive explanations as if it were a unified form of explanation when it is not, where Correia makes a similar mistake in taking 'because' to provide an informal understanding of grounding.[15] In opposition to such views, I will take 'grounding' to regiment the constitutive reading of 'sufficient for' outlined above. Given this identification, there is good reason to interpret `(B)` as a grounding claim since having ceramic structure C strictly implies that the teacup is brittle without including anything irrelevant to the teacup being brittle, or showing any sensitivity to differences in guise.

Instead of taking grounding to regiment a constitutive explanatory reading of 'sufficient for', Schaffer takes a different approach, assuming that grounding is an ontological dependence relation with an Aristotelian pedigree.[16] In particular, Schaffer (2009) presents the following quote from Barnes' translation of Aristotle's *Categories*, along with Gill's (1989) interpretation given below:

> So if the primary substances did not exist it would be impossible for any of

[15] Schaffer (2017, p. 303) considers ontologically neutral formulations which employ the idioms 'explains' and 'reason why', taking certain instances to be, "clearly non-causal, and moreover have the feel of concerning the constitutive generation of a dependent outcome." Not only is this gloss unhelpful in its obscurity, the explanatory idioms that Schaffer focuses on also fail to distinguish the different forms of constitutive explanation with which I will be concerned.

[16] Schaffer (2009, p. 376) makes some puzzling remarks about his term '\' for grounding differing from predicate notation in accepting arguments of any grammatical type, though says nothing to suggest what kind of background type theory would make such constructions well-formed, not to mention what would motivate such a grammar for grounding.

> the other things to exist. Aristotle (1984, p. 5; *Cat.* 2b6-7)
>
> In the *Categories* the main criterion is ontological priority. An entity is ontologically primary if other things depend for its existence on it, while it does not depend in a comparable way on them. The primary substances of the *Categories*, such as particular men and horses, are subjects that ground the existence of other things... Gill (1989, p. 3)

Schaffer goes on to defend what he refers to as a neo-Aristotelian approach to ontology according to which, "there is no longer any harm in positing an abundant roster of existents, *provided it is grounded on a sparse basis*" (p. 353).[17] The entities in the sparse basis are supposed to be fundamental, where an entity is fundamental just in case it is not grounded in anything. For my purposes, I will remain neutral about whether all ontological commitments of a theory carry the same theoretical cost, or whether one should follow Schaffer in only taking the fundamental ontological commitments of a theory to be costs. Nevertheless, we may admit that if ontological dependence were to play this role in measuring the ontological costs of a theory as opposed to its ontological commitments following Quine, then there would be an important theoretical role for such a notion of grounding to play, at least insofar as ontological parsimony is taken into account in theory choice.[18]

In contrast to the different forms of constitutive explanation, ontological dependence claims are peculiar to metaphysics. Although one can stipulate a meaning for ontological dependence, one cannot stipulate that such a notion is theoretically valuable. Rather, defenders of ontological dependence must indicate what theoretical work ontological dependence is uniquely qualified to do within metaphysics. By contrast, the presence of the different forms of constitutive explanation throughout systematic inquiry goes considerable ways towards establishing the theoretical value of such explanatory locutions without appealing to any specific ambitions

[17] Schaffer's emphasis. See also Schaffer (2015) for further elaboration of such views.

[18] Wilson (2014) appears to dismiss this theoretical role for ontological dependence to play in claiming that there is no theoretical work for a general notion of ontological dependence.

within metaphysics, or philosophy more generally. Nevertheless, an account of ontological dependence may be worth developing. In particular, it is natural to draw on a constitutive explanatory reading of 'necessary for' in order to provide the following definition:

Ontological Dependence: α ontologically depends on β iff for α to exist it is necessary for β to exist.

Assuming a Quinean theory of existence where α exists just in case something is identical to α, ontological dependence specifies what objects there must be for there to be a given object.[19] For instance, it is clear how the existence of every singleton requires its sole member to exist, or how the existence of the holes in a piece of cheese require the cheese to exist.[20] Such examples help to illustrate the difference between the theoretical role for ontological dependence as compared with the present understanding of grounding. Rather than explaining anything or being explained by anything themselves, objects may at most be said to participate in explanations as witnessed by instances of the definiens of *Ontological Dependence* given above. Accordingly, I will exclude further consideration of ontological dependence as irrelevant to the present concern with grounding as a form of constitutive explanation.

4 Theories of Essence

In a seminal paper, Fine (1994) argued that quantified modal logic does not possess the expressive resources needed to provide an adequate account of the essence of an object. In particular, one cannot determine whether a property is essential to a given object by checking whether the object in question has that property in every

[19] For related definitions of ontological dependence, see Fine (1995b) and Fine (2010, p. 582).
[20] Schaffer (2009, p. 375) explicitly mentions these examples.

possibility in which it exists.[21] For instance, Fine asks:

> For can we not recognize a sense of nature, or of "what an object is", according to which it lies in the nature of the singleton to have Socrates as a member even though it does not lie in the nature of Socrates to belong to the singleton? (p. 5)

The locution 'it lies in the nature of' is not likely to occur outside of metaphysics. Although one may stipulate a meaning for such locutions, or else appeal to some body of systematic use within metaphysics, I will restrict attention to common constructions which occur across a wide range of disciplines, and not just metaphysics. Nevertheless, we may say much the same thing in common language. In particular, we may characterise the asymmetry which Fine brings to light by using 'part of what it is to be' in the following way:

`(S)` Containing Socrates as a member is *part of what it is* to be {Socrates}.

`(#S)` Being a member of {Socrates} is *part of what it is* to be Socrates.

As Fine points out, it follows from plausible assumptions about impure sets that Socrates is a member of his singleton in every possibility in which either of them exist. Even though `(S)` is clearly true, `(#S)` is false since, "It is no part of the essence of Socrates to belong to the singleton" (p. 4-5). However, the modal account of essence makes `(S)` and `(#S)` necessarily equivalent, and so fails to provide an adequate account of the essence of an object.

Although impure sets are beyond the pale of day-to-day contemplation, similar considerations extend to many common cases. For instance, it is natural to claim that being painted by Leonardo da Vinci is part of what it is to be the Mona Lisa, where indeed no replica should be confused with the Mona Lisa on account of such

[21] Fine (1994, p. 4) also considers a Moorean account in which, "an object is taken to have a property essentially just in case it is necessary that the object has the property if it is identical to that very object." Given plausible assumptions, Fine shows that the Moorean account is no different than the account provided above.

considerations. Or to take another example, one might claim that being the son of Sophroniscus and Phaenarete is part of what it is to be Socrates. More generally, we may consider claims of the form:

Objectual Essence: To G is part of what it is to be α.

Given that 'α' takes nominal position and 'G' takes one-place predicate position, objectual essence claims relate objects to the ways that those objects must be in order to be what they are. Although it is convenient to refer to such "ways" as properties, turning what is otherwise expressed by terms that take predicate position into objects over which we may quantify, objectual essence claims do not include nominal terms which refer to properties, truths, facts or any other entities. Accordingly, we may speak loosely of which properties are essential to which objects without officially including properties in the domain of objects over which our first-order quantifiers range.

Whereas it is common to make claims about part of what it is to be a given object, it is far less natural to make claims about part of what it is to be some objects, unless of course this is to be understood as the disjunction of some range of singular objectual essence claims. Nevertheless, Fine (1995a, p. 241-2) shifts primary attention to plural formulations which he reads informally as:

Plural Essence: A in virtue of the nature of the objects which F.[22]

It is important to stress that on Fine's intended reading of plural essence claims, 'F' merely serves to identify the objects whose natures are under discussion. By contrast, Correia (2006, p. 757) focuses on constructions of the form:

Generic Essence: An F, as such, essentially Gs.

[22] I have omitted 'is true' following 'A' in Fine's (1995a) original formulation since his aim is not to assert anything metalinguistic, but rather to say in virtue of what it is the case that A.

Correia (p. 759) emphasises the difference between plural and generic essence claims by writing, "Plausibly, bachelors, as such, are essentially unmarried. But many actual men are bachelors and fail to be essentially unmarried." As this example highlights, considering what lies in the nature of some range of objects as a proxy for considering some property which those objects share in common is liable to yield the wrong results. For instance, suppose that Cain and Abel were the only bachelors: although being born of Adam and Eve is essential to the objects that happen to be bachelors, being born of Adam and Eve is not essential to being a bachelor.

Instead of asking about the nature of the objects which happen to have a given property, Correia is right to focus on which properties are essential for which. For instance, we may ask which properties are essential for being a bachelor such as the property of being unmarried. Nevertheless, generic essence claims of the form given above are unlikely to occur outside of metaphysics, and so it is natural to worry that such claims may fail to have a robust meaning without stipulating conventions for how generic essence claims are to be understood. Rather than attempting to make such clarifications, we do better to contrast plural essence claims with claims of the following form:

Property Essence: To G is part of what it is to F.

It is perfectly natural to claim that to be unmarried is part of what it is to be a bachelor. By contrast, being unmarried is not part of what it is to be those individuals who happen to be bachelors, for indeed many of the men who are bachelors may go on to get married without ceasing to be themselves. Instead of being concerned with part of what it is to be the objects which have a given property, it is far more natural to ask what it is to have a given property, attempting at least partial answers by indicating some further properties. For instance, being a mammal is part of what it is to be a whale, being equilateral is part of what it is to be square, and being a fermion is part of what it is to be an electron. As these examples suggest, such claims occur across a wide range of disciplines rather than only occurring within metaphysics.

In addition to the essence of one-place properties, it is natural to consider the essence of n-place relations, as well as operators of any arity. In order to accommodate such cases, Fine (2015, p. 299) considers claims of the following form, where 'x', 'y', ... are variables, and 'ψ' and 'φ' are open sentences:

Bound Essence: It is essential to $x, y, \ldots$ satisfying ψ that ϕ be the case.[23]

Far from quotidian, such claims do not belong to common English. For instance, such claims appear on their face to concern satisfaction. Although this is not to assume that such claims are unintelligible, we cannot rely on a common understanding of English in order to make sense of bound essence claims. Moreover, there is no need to depart from common English in order to assert a wide range of essence claims which relate more than one-place properties:

(D) One being the offspring of another is part of what it is for the former to be the daughter of the latter.

(K) Believing that such-and-such is the case is part of what it is for one to know that such-and-such is the case.

Observe that in both (D) and (K), 'part of what it is *for*' has been employed instead of 'part of what it is *to*', where 'one', 'another', and 'such-and-such' specify how the arguments of one expression (e.g., 'to know that') relate to the arguments

[23] Whereas Fine (2015) considers what is essential to $x, y, \ldots$ satisfying $\psi_1, \psi_2, \ldots$, one may assert something similar by considering what is essential to $x, y, \ldots$ satisfying $\psi_1 \wedge \psi_2 \wedge \ldots$, at least for a finite number of arguments. If one is concerned to extend consideration to an infinite number of arguments, such ambitions are best accommodated by introducing the infinite conjunction operator '$\bigwedge$', studying its interaction with an operator for essence. Similar considerations discourage taking a many-one grounding operator to be primitive.

of the other (e.g., 'to believe that'). Abstracting from the details of these cases, I will focus on essentialist claims of the following general form:

> *Propositional Essence:* For it to be the case that A is part of what it is for it to be the case that B.

For present purposes, I will take 'part of what it is for' and a constitutive reading of 'necessary for' to by synonymous. Just as 'ground' was taken to be a label for a constitutive reading of the locution 'sufficient for', I will take 'essence' to be a label for a constitutive reading of 'necessary for'.

In shifting attention from bound essence claims of the kind that Fine considers to propositional essence claims, it remains to clarify how such claims are to be interpreted. In particular, nothing has been said so far about how 'one', 'another', and 'such-and-such' are to be understood in `(D)` and `(K)`. Although one might interpret such terms as variables of the appropriate type which are bound by universal quantifiers that take wide scope, Fine (2015) takes such terms to designate arbitrary objects, and Correia and Skiles (2019) take such terms to be variables bound by the essence operator itself, where a thorough investigation of such alternatives requires the development and comparison of quantified logics for essence with identity. It is only once such a logic has been developed and adequately defended that one may provide an account of the relationships between claims of objectual essence, property essence, and propositional essence.[24] However, prior to exploring the interactions between quantification, essence, and identity, it is natural to begin by developing a propositional logic for essence, studying the interaction between essence and a range of other propositional operators. With this aim in mind, the following section will provide a logic with the expressive power needed to regiment propositional essence claims in addition to including sentential operators for grounding, the metaphysical modals, and the truth-functional operators.

[24] For instance, consider the definitions $\Box_\alpha F := F(x) \sqsubseteq_x (\alpha = x)$ and $A \sqsubseteq_{\vec{v}} B := \forall \vec{v}(A \sqsubseteq B)$ where $\ulcorner A \sqsubseteq B \urcorner$ reads $\ulcorner$For it to be the case that A is necessary for it to be the case that $B\urcorner$.

5 A Logic for Constitutive Explanation

In just the same way that the metaphysical necessity and possibility operators are interdefinable in a language with negation, so too essence, ground, reduction, and propositional identity are interdefinable in a language with operators for the truth-functions. Accordingly, there is no need to include more than one primitive hyperintensional operator, and so as a matter of convention I will take grounding to be primitive.[25] Letting $\mathbb{L} = \{p_i : i \in \mathbb{N}\}$ be the set of *sentence letters* of $\mathcal{L}$, where the primitive operators '$\neg$', '$\wedge$', '$\vee$', '$\Box$', and '$\leqslant$' express negation, conjunction, disjunction, metaphysical necessity, and grounding respectively, we may define the *well-formed sentences* of $\mathcal{L}$ as:

$$A ::= p \mid \neg A \mid A \wedge A \mid A \vee A \mid \Box A \mid A \leqslant A.$$

Letting $\texttt{wfs}(\mathbb{L})$ be the set of all well-formed sentences of $\mathcal{L}$, this section provides a proof system by which to derive a range of theorems and rules of inference for reasoning with constitutive explanatory language. As I will show, the resulting space of principles captures the theoretical target set out in §1 by including analogues for each of the informal principles originally defended.

It will be important to begin by defining a number of further operators. Although no more than metalinguistic conventions, the definitions given below are substantive insofar as the defined operators correspond to independently meaningful concepts that could just as well have been included in $\mathcal{L}$ as distinct primitives. Nevertheless, the present treatment aims to balance complexity with intelligibility by maintaining the following metalinguistic abbreviations:

Material Conditional: $A \rightarrow B := \neg A \vee B$.

Possibility: $\Diamond A := \neg\Box\neg A$.

[25] Compare Brast-McKie (2021) where propositional identity is taken to be primitive.

Essence: $A \sqsubseteq B := \neg A \leqslant \neg B$.

Weak Reduction: $A \Rightarrow B := (A \sqsubseteq B) \wedge (A \leqslant B)$.

Strict Reduction: $A \Mapsto B := (A \Rightarrow B) \wedge (B \not\Rightarrow A)$.

Relevance: $A \preceq B := A \wedge B \leqslant B$.

Identity: $A \equiv B := (A \leqslant B) \wedge (B \leqslant A)$.

Whereas it is common to adopt the definitions for the material conditional and the metaphysical possibility operator, considerably more must be said in defence of the remaining conventions indicated above. In order to provide these arguments, it will be important to stipulate how the primitive operators in $\mathcal{L}$ are to be used, employing the abbreviations above as needed.

I will define *The Logic of Constitutive Explanation* (CE) by way of the axioms, rules of inference, and meta-rules of inference given below, where $A, B, C \in \texttt{wfs}(\mathbb{L})$ and $\Box\Gamma := \{\Box A : A \in \Gamma\}$ for any set $\Gamma \subseteq \texttt{wfs}(\mathbb{L})$:

A1 $A \equiv \neg\neg A$.

A2 $A \wedge (B \wedge C) \equiv (A \wedge B) \wedge C$.

A3 $\neg(A \wedge B) \equiv \neg A \vee \neg B$.

A4 $\neg(A \vee B) \equiv \neg A \wedge \neg B$.

A5 $A \wedge B \leqslant B \wedge A$.

A6 $A \wedge B \leqslant A \vee B$.

A7 $A \leqslant A \vee B$.

A8 $B \leqslant A \vee B$.

A9 $A \wedge (B \vee C) \leqslant (A \wedge B) \vee (A \wedge C)$.

A10 $A \vee (B \wedge C) \leqslant (A \vee B) \wedge (A \vee C)$.

A11 $\Box A \to A$.

A12 $\Diamond A \to \Box\Diamond A$.

R1 $A \to B,\ A \vdash B$.

R2 $A \leqslant B,\ B \leqslant C \vdash A \leqslant C$.

R3 $A \leqslant C,\ B \leqslant C \vdash A \vee B \leqslant C$.

R4 $A \leqslant B,\ A \leqslant C \vdash A \leqslant B \wedge C$.

R5 $A \leqslant B \vdash A \vee B \sqsubseteq B$.

R6 $A \leqslant B \vdash B \sqsubseteq A \vee B$.

R7 $A \leqslant B \vdash \Box(A \to B)$.

R8 $A \leqslant B \vdash \Box(A \leqslant B)$.

M1 If $\Gamma, A \vdash B$, then $\Gamma \vdash A \to B$.

M2 If $\Gamma, \neg A \vdash B$ and $\Gamma, \neg A \vdash \neg B$, then $\Gamma \vdash A$.

M3 If $\Gamma \vdash A$ and $\Gamma \vdash B$, then $\Gamma \vdash A \wedge B$.

M4 If $\Gamma \vdash A$, then $\Box\Gamma \vdash \Box A$.

Let $\vdash_{\text{CE}}$ be the smallest relation that satisfies the axioms and rules provided above which is closed under the standard structural rules, where ⌜$\Gamma \vdash_{\text{CE}} A$⌝ reads ⌜$A$ is provable in CE from the premises included in Γ⌝. Since ambiguity will not threaten, it will be convenient to drop '$_{\text{CE}}$' from '$\vdash_{\text{CE}}$'. It remains to argue that CE provides an adequate logic for reasoning with constitutive explanatory language. Accordingly, the remainder of the paper will endeavour to show that $\mathcal{L}$ includes the expressive resources needed to regiment constitutive explanatory readings of 'necessary for', 'sufficient for', and 'what it is for' which respect the theoretical roles attributed to these notions above.[26]

Given the deductive resources of CE, it will be important to defend the abbreviations stipulated above. Beginning with Essence, consider the following informal principles for 'necessary for' and 'sufficient for':

Duality: (E) If for it to be the case that A is necessary for for it to be the case that B, then it not being the case that A is sufficient for it not being the case that B.

(G) If for it to be the case that A is sufficient for for it to be the case that B, then it not being the case that A is necessary for it not being the case that B.

I take the informal principles given above to possess a significant degree of intuitive appeal regardless of whether one assumes a constitutive or purely modal reading of 'necessary for' and 'sufficient for'. For instance, if having 79 protons is necessary for an atom to be gold, then failing to have 79 protons is sufficient for an atom to not be gold. Or to take another case, if harming for fun is sufficient for an action to be wrong, then not harming for fun is necessary for an action to not be wrong. Insofar

[26] As I show in Brast-McKie (draft), CE is sound over a well motivated semantic theory.

as one accepts both (E) and (G), it is natural to maintain their formal analogues, whereby it follows from **A1** that $A \leqslant B$ and $\neg A \sqsubseteq \neg B$ are interderivable, and so equivalent within CE.[27] Even if Essence is not taken to provide an informative analysis, these results show that Essence is at least extensionally adequate, and so the definition may nevertheless be maintained as a harmless abbreviation.

Given Essence, we may proceed to justify Weak Reduction by observing that the definition closely resembles the informal account given by *Reduction*. However, insofar as grounding is to provide a reasonably faithful regimentation of a constitutive reading of 'sufficient for', it is natural to take grounding to be reflexive. Accordingly, we may accept all instances of the following:

Reflexivity: $A \leqslant A$.

For instance, although perfectly trivial, it is reasonable to admit that having 79 protons is sufficient for having 79 protons.[28] Given the reflexivity of grounding, it follows that essence is also reflexive by Essence, and so weak reduction is reflexive given Weak Reduction. Although there is a trivial sense in which being prime is what it is for the number 7 to be prime, where something similar may be said for other cases, it is often natural to take explanatory readings of 'what it is for'-claims to assert a degree of explanatory asymmetry. Thus Strict Reduction defines an operator which asserts both that the explanandum weakly reduces to the explanans, and that the converse does not also hold, thereby capturing the desired explanatory asymmetry.

It remains to justify Relevance and Identity. Rather than appealing to their informal readings in support of adopting these definitions, Brast-McKie (draft) provides semantic arguments for maintaining these abbreviations. In particular,

[27] *Proof:* Assuming $\neg A \sqsubseteq \neg B$, it follows from the formalisation of (E) that $\neg\neg A \leqslant \neg\neg B$, where $A \leqslant B$ is the result of two instances of **AR16** given **A1**. Given the formalisation of (G), we may conclude that $A \leqslant B$ and $\neg A \sqsubseteq \neg B$ are interderivable. □

[28] Of course, once it has been stipulated that grounding is reflexive, one may define *strict grounding* as $A < B := (A \leqslant B) \wedge (B \nleqslant A)$ which is irreflexive.

I develop a semantics and theory of logical consequence for $\mathcal{L}$ which validates a collection of core principles in $\mathcal{L}$ that can all be intuitively justified. Insofar as the semantic constraints are all motivated by the ambition to validate intuitively justified principle, we may take validity to confer justification on a wider space of principles than those principles for which there is strong intuitive justification. As I show, both Relevance and Identity are extensionally adequate given the semantics for $\mathcal{L}$, and so may be accepted at least as harmless abbreviations. Accordingly, I will turn to provide justification for adopting CE by observing that **A1** − **A4** belong to Boolean theories of propositions. Insofar as Boolean theories of propositions have proven to be of considerable theoretical utility for studying languages with truth-functional and modal operators, a conservative methodology recommends maintaining the Boolean identities in the absence of countervailing considerations. Thus there is no need to defend **A1** − **A4**, where the same may be said of **A5** which may be shown to be interderivable with the Boolean identity $A \wedge B \equiv B \wedge A$ so long as grounding is assumed to be reflexive and transparent.

Rather than defending the inclusion of such axioms as **A1** − **A5**, what is required is an account of why all of the Boolean identities have not been included in CE. Here we may appeal to the *First-Degree Logic of Propositional Identity* (PI^1) which I argue in Brast-McKie (2021) provides a minimal departure from intensional theories of propositions while nevertheless respecting differences in subject-matter in addition to differences in modal profile. Given that constitutive explanations require their explanans to be wholly relevant to their explanandum, where one proposition is wholly relevant to another just in case the subject-matter of the former is "part" of the subject-matter of the latter, it is natural to take CE to maintain the same distinctions between propositions as PI^1.[29] For instance, Boolean identities such as $A \vee \neg A \equiv B \vee \neg B$ have been excluded from both PI^1

[29] As brought out in Brast-McKie (2021), "part" may be understood in terms of either essence or ground since $A \preceq B := \sigma A \leqslant \sigma B$ and $A \preceq B := \sigma A \sqsubseteq \sigma B$ are coextensive, where σA is the subject-matter of A.

and CE since $A \vee \neg A$ and $B \vee \neg B$ may differ in subject-matter despite having the same modal profile. As brought out below, PI^1 is derivable in CE, from which it follows that CE does not distinguish between propositions that are identified in PI^1. Insofar as CE is to respect the same distinctions between propositions as PI^1, CE should not include identities that are not derivable in PI^1. It is for this reason that the other Boolean identities besides **A1** − **A5** have been excluded from CE.

We may now justify **A6** − **A8** by appealing to the inclusive reading of the disjunction operator. In particular, A, B, and $A \wedge B$ are all sufficient for $A \vee B$ on a constitutive reading of 'sufficient for' since the former strictly imply the latter while also being wholly relevant to the latter, and showing any sensitivity to differences in guise. Insofar as grounding is intended to regiment constitutive readings of 'sufficient for', we find reason to maintain **A6** − **A8**. It is worth observing that the corresponding principles **E1** − **E3** given below may then be derived for essence. Whereas **A6** − **A8** may be thought to be characteristic of ground, **E1** − **E3** may similarly be taken to be characteristic of essence. By contrast, the following principles all admit of exceptions:

#1 $A \wedge B \leqslant A$.	**#2** $A \vee B \sqsubseteq A$.
#3 $A \wedge B \leqslant B$.	**#4** $A \vee B \sqsubseteq B$.
#5 $A \leqslant A \wedge B$.	**#6** $A \sqsubseteq A \vee B$.
#7 $B \leqslant A \wedge B$.	**#8** $B \sqsubseteq A \vee B$.
#9 $A \vee B \leqslant A \wedge B$.	**#10** $A \wedge B \sqsubseteq A \vee B$.

Whereas **#1** − **#4** are to be excluded from CE on account of the explanans failing to be wholly relevant to the explanandum, **#5**, **#7**, and **#9** are to be excluded on account of the explanans failing to strictly imply the explanandum, and **#6**, **#8**, and **#10** are to be excluded on account of the explanans failing to be strictly implied by the explanandum.

Instead of providing intuitive motivation for including **A9** and **A10** in CE, I will rely on their validity over the semantics defended in Brast-McKie (draft). In order to indicate why the converses of these principles have been excluded, we may observe that if the converses of **A9** and **A10** were to belong to CE, then it would follow from Identity that analogues of **A9** and **A10** would hold as propositional identities. However, as I argue in Brast-McKie (2021), disjunction does not distribute over conjunction, nor does conjunction distribute over disjunction as in standard Boolean theories.

We may now turn to justify the modal axioms and rules included in CE. Assuming that S5 is the correct logic for metaphysical modality for the sake of simplicity, we find reason to include **A11** and **A12** so as to derive S5 within CE. Although K has not been included as an axiom, it is easy to derive K from **M4** given **R1** and **M1**, where the rule of necessitation is a special case of **M4**.[30] Additionally, **R7** has been included to capture *Implication* (g) defended above, where analogues for essence and reduction may then be derived in CE as given below. The last modal principle to defend is **R8** which asserts the non-contingency of grounding, where the analogous principles may be derived for both essence and reduction. In support of maintaining **R8**, we may consider the result of supposing that **R8** were to admit of exceptions. It follows that there must be some A and B where $A \leqslant B$ holds in a possibility w, but $\Box(A \leqslant B)$ does not hold in w. Accordingly, there must be some further possibility u which is accessible from w where $A \leqslant B$ does not hold. Nevertheless, it follows by **R7** that $\Box(A \to B)$ holds in w, and so $\Box\Box(A \to B)$ also holds in w given the theorems of S5. Thus $\Box(A \to B)$ must hold in u given that u is accessible from w. Whereas one might account for why $\Box(A \to B)$ holds in w by appealing to the fact that $A \leqslant B$ also holds in w, the same explanation cannot so easily be provided for why $\Box(A \to B)$ holds in u since $A \leqslant B$ does not hold in u. In order to avoid this circumstance, I will include **R8** in CE.

[30] *Proof:* $\Box(A \to B)$, $\Box A \vdash \Box B$ follow from **R1** by **M4**, where **K** then follows by **M1**. $\Box$

It remains to justify the non-modal rules included in CE. We may begin by observing that **R1** together with **M1** − **M3** yield classical propositional logic which I will refer to as PL. Given that the present exploration does not provide motivation for giving up classical reasoning, I will take it to be consistent with a conservative methodology that CE entail PL, thereby justifying the inclusion of **R1** and **M1** − **M3**. Next we may observe that **R2** − **R4** have natural informal readings where '$\leqslant$' reads 'sufficient for'. Insofar as grounding is intended to regiment a constitutive reading of 'sufficient for', there is good reason to maintain each of these principles. In particular, we may observe that **R2** − **R4** respect *Implication* (G) as well as the requirement that the explanans be wholly relevant to its explanandum. For instance, if A and B are each sufficient for C, then it follows that A and B are both wholly relevant to C and strictly imply C, and so $A \vee B$ will also be wholly relevant to C and strictly imply C. By contrast, **R5** and **R6** cannot be justified by appealing to their informal readings, and so I will rely on the semantic arguments provided in Brast-McKie (draft) in support of these final principles.

In order to provide some sense of the deductive power of CE, consider the following admissible rules of inferences and theorems for CE, taking $\ulcorner C_{(A/B)} \urcorner$ to be the result of replacing one or more occurrences of $\ulcorner B \urcorner$ in $\ulcorner C \urcorner$ with $\ulcorner A \urcorner$:

Admissible Rules

AR1 $A,\ A \leqslant B\ \vdash B.$

AR2 $\neg B,\ A \leqslant B\ \vdash \neg A.$

AR3 $B,\ A \sqsubseteq B\ \vdash A.$

AR4 $\neg A,\ A \sqsubseteq B\ \vdash \neg B.$

AR5 $A \sqsubseteq B,\ A \sqsubseteq C\ \vdash A \sqsubseteq B \vee C.$

AR6 $A \sqsubseteq B,\ C \sqsubseteq D\ \vdash A \wedge C \sqsubseteq B \wedge D.$

AR7 $A \sqsubseteq C,\ B \sqsubseteq C\ \vdash A \wedge B \sqsubseteq C.$

AR8 $A \leqslant B,\ C \leqslant D\ \vdash A \vee C \leqslant B \vee D.$

AR9 $A \sqsubseteq B\ \vdash\ A \wedge B \leqslant B.$

AR10 $A \sqsubseteq B\ \vdash\ B \leqslant A \wedge B.$

AR11 $A \sqsubseteq B\ \vdash\ \Box(B \rightarrow A).$

AR12 $A \sqsubseteq B\ \vdash\ \Box(A \sqsubseteq B).$

AR13 $A \leqslant B\ \vdash A \preceq B.$

AR14 $A \sqsubseteq B\ \vdash A \preceq B.$

AR15 $A \sqsubseteq B,\ B \sqsubseteq C\ \vdash A \sqsubseteq C.$

AR16 $A \equiv B,\ C\ \vdash C_{(A/B)}.$

Essence Theorems

E1 $A \sqsubseteq A \wedge B$. **E2** $B \sqsubseteq A \wedge B$. **E3** $A \vee B \sqsubseteq A \wedge B$.

Relevance Theorems

RL1 $A \preceq A \vee B$ **RL2** $A \preceq A \wedge B$

RL3 $B \preceq A \vee B$ **RL4** $B \preceq A \wedge B$

Identity Theorems and Rules

ID1 $A \wedge A \equiv A$. **ID2** $A \vee A \equiv A$.

ID3 $A \wedge B \equiv B \wedge A$. **ID4** $A \vee B \equiv B \vee A$.

ID5 $A \wedge (B \wedge C) \equiv (A \wedge B) \wedge C$. **ID6** $A \vee (B \vee C) \equiv (A \vee B) \vee C$.

ID7 $\neg(A \wedge B) \equiv \neg A \vee \neg B$. **ID8** $\neg(A \vee B) \equiv \neg A \wedge \neg B$.

ID9 $A \equiv \neg\neg A$. **IR1** $A \equiv B \vdash B \equiv A$.

IR2 $A \equiv B \vdash (A \wedge C) \equiv (B \wedge C)$. **IR3** $A \equiv B \vdash (A \vee C) \equiv (B \vee C)$.

IR4 $A \equiv B,\ B \equiv C \vdash A \equiv C$. **IR5** $A \equiv B \vdash \neg A \equiv \neg B$.

Reduction Theorems and Rules

RT1 $A \Rightarrow A \wedge (A \vee B)$. **RT2** $A \vee (B \wedge C) \Rightarrow (A \vee B) \wedge (A \vee C)$.

RT3 $A \Rightarrow A \vee (A \wedge B)$. **RT4** $A \wedge (B \vee C) \Rightarrow (A \wedge B) \vee (A \wedge C)$.

RT5 $A \Rightarrow A$. **RR1** $A \Rightarrow B, B \Rightarrow A \vdash A \equiv B$.

RR2 $A \Rightarrow B \vdash \Box(A \leftrightarrow B)$. **RR3** $A \Rightarrow B \vdash A \preceq B$.

RR4 $A \Mapsto B \vdash B \not\Mapsto A$. **RR5** $A \Mapsto B, B \Mapsto C \vdash A \Mapsto C$.

RR6 $A \Mapsto B \vdash \Box(A \leftrightarrow B)$. **RR7** $A \Mapsto B \vdash A \preceq B$.

Without reviewing each of the theorems and rules given above, it is worth making a number of observations. To begin with, we may note that the theorems and rules for propositional identity are identical to PI[1] as presented in Brast-McKie (2021), providing strong abductive justification in support of Identity. Even if Identity is not taken to provide an informative definition of propositional identity, the convention is nevertheless extensionally adequate, and so may be maintained as a harmless abbreviation.

Insofar as '$\equiv$' expresses propositional identity, **AR16** captures the idea that $\mathcal{L}$ is a transparent language, where a language $\mathcal{L}$ is *transparent* just in case every operator $\mathcal{Q}$ in $\mathcal{L}$ is transparent.[31] Formalising the definition given above, we may stipulate that an operator $\mathcal{Q}$ is *transparent* in a language $\mathcal{L}$ just in case all instances of the following principle hold, where $\ulcorner \vec{O}_{(B/A)} \urcorner$ is the result of freely substituting $\ulcorner B \urcorner$ for $\ulcorner A \urcorner$ in the sequence of $\mathcal{Q}$'s operands $\ulcorner \vec{O} \urcorner$:

$$\textbf{Func} \quad (A \equiv B) \rightarrow [\mathcal{Q}(\vec{O}) \equiv \mathcal{Q}(\vec{O}_{(B/A)})].$$

Intuitively, transparent languages are insensitive to mere differences in guise on account of only including terms which operate on the propositions expressed by the sentences of that language independent of the particular means of their expression. Although many fields such as physics and chemistry are most naturally developed in transparent languages, metaphysics in particular may be said to be concerned with the axiomatisation of transparent operators. Insofar as the study of constitutive explanation falls within the purview of metaphysics, it is right to assume that the language $\mathcal{L}$ for the logic of constitutive explanation CE ought to be transparent as guaranteed by **AR16**.[32]

Having reviewed CE, we may consider the manner in which essence, grounding, and reduction capture the theoretical roles that constitutive explanatory readings of 'necessary for', 'sufficient for', and 'what it is for' were found to play. By taking Weak Reduction and Strict Reduction to disambiguate weak and strict readings of 'what it is for'-claims, **RR4** shows that strict reduction accommodates the exceptions taken to *Reduction Symmetry*. Additionally, **R7**, **AR11**, and **RR2** capture the *Implication* principles, where **AR13**, **AR14**, **RR3**, and **RR7** capture

[31] **P2** in Brast-McKie (2021) proves that a propositional language is transparent just in case **LL** holds without exception, where **LL** is interderivable with **AR16** given **M1**.

[32] As I show in Brast-McKie (2021), **AR16** fails in Correia and Skiles' (2019) logic.

the requirement that the explanans be wholly relevant to its explanandum in any constitutive explanation. Moreover, **AR16** entails that essence, ground, and reduction are transparent operators in accordance with the claim that constitutive explanations are insensitive to differences in guise. Accordingly, I will take essence, grounding, and strict reduction to adequately regiment constitutive explanatory readings of the target locutions 'necessary for', 'sufficient for', and 'what it is for'. In addition to providing a setting in which a range of further constitutive explanatory operators may be defined, CE provides an initial description of how to reason with constitutive explanatory language. For these reasons I will take CE to satisfy the initial aim set out above to provide a theory for the varieties of constitutive explanation.

References

Aristotle. 1984. *Complete Works of Aristotle, Volume 1: The Revised Oxford Translation*. Princeton, NJ: Princeton University Press. ISBN 978-0-691-01650-4.

Brast-McKie, Benjamin. 2021. "Identity and Aboutness." *Journal of Philosophical Logic* 50:1471–1503. ISSN 1573-0433. doi:10.1007/s10992-021-09612-w.

—. draft. "A State Semantics for a Modalised Logic of Constiutive Explanation." *Journal of Philosophical Logic* .

Correia, Fabrice. 2006. "Generic Essence, Objectual Essence, and Modality." *Nous* 40:753–767. doi:10.1111/j.1468-0068.2006.00632.x.

—. 2008. "Ontological Dependence." *Philosophy Compass* 3:1013–1032. ISSN 1747-9991. doi:10.1111/j.1747-9991.2008.00170.x.

—. 2010. "Grounding and Truth-Functions." *Logique Et Analyse* 53:251.

—. 2014. "Logical Grounds." *The Review of Symbolic Logic* 7:31–59. ISSN 1755-0211. doi: 10.1017/S1755020313000300.

Correia, Fabrice and Schnieder, Benjamin. 2012. "Grounding: An Opinionated Introduction." In Fabrice Correia and Benjamin Schnieder (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, 1. Cambridge University Press.

Correia, Fabrice and Skiles, Alexander. 2019. "Grounding, Essence, and Identity." *Philosophy and Phenomenological Research* 98:642–670. ISSN 1933-1592. doi:10.1111/phpr.12468.

Dasgupta, Shamik. 2014. "On the Plurality of Grounds." *Philosopher's Imprint* 14. ISSN 1533-628X.

—. 2017. "Constitutive Explanation." *Philosophical Issues* 27:74–97. ISSN 1758-2237. doi: 10.1111/phis.12102.

Fine, Kit. 1994. "Essence and Modality." *Philosophical Perspectives* 8:1–16. ISSN 1520-8583. doi:10.2307/2214160.

—. 1995a. “The Logic of Essence.” *Journal of Philosophical Logic* 24:241–273.

—. 1995b. “Ontological Dependence.” *Proceedings of the Aristotelian Society* 95:269–290.

—. 2001. “The Question of Realism.” *Philosophers' Imprint* 1:1–30.

—. 2010. “Towards a Theory of Part.” *The Journal of Philosophy* cvii:559–589.

—. 2012a. “Guide to Ground.” In Fabrice Correia and Benjamin Schnieder (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, 37–80. Cambridge: Cambridge University Press.

—. 2012b. “The Pure Logic of Ground.” *The Review of Symbolic Logic* 5:1–25. ISSN 1755-0211. doi:10.1017/S1755020311000086.

—. 2015. “Unified Foundations for Essence and Ground.” *Journal of the American Philosophical Association* 1:296–311. ISSN 2053-4477. doi:10.1017/apa.2014.26.

Gill, Mary Louise. 1989. *Aristotle on Substance: The Paradox of Unity.* Princeton, N.J: Princeton University Press. ISBN 978-0-691-07334-7.

Krämer, Stephan and Roski, Stefan. 2015. “A Note on the Logic of Worldly Ground.” *Thought: A Journal of Philosophy* 4:59–68. ISSN 2161-2234. doi:10.1002/tht3.158.

Litland, Jon Erling. 2016. “Pure Logic of Many-Many Ground.” *Journal of Philosophical Logic* 1–47. ISSN 0022-3611, 1573-0433. doi:10.1007/s10992-015-9386-2.

—. 2018. “Pure Logic of Iterated Full Ground.” *The Review of Symbolic Logic* 11:411–435. ISSN 1755-0203, 1755-0211. doi:10.1017/S1755020317000211.

Rosen, Gideon. 2010. “Metaphysical Dependence: Grounding and Reduction.” *Modality: Metaphysics, Logic, and Epistemology* 109–136.

Schaffer, Jonathan. 2009. “On What Grounds What.” In David Manley, David J. Chalmers, and Ryan Wasserman (eds.), *Metametaphysics: New Essays on the Foundations of Ontology*, 347–383. Oxford University Press.

—. 2012. “Grounding, Transitivity, and Contrastivity.” In Fabrice Correia and Benjamin Schnieder (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, 122–138. Cambridge University Press.

—. 2015. “What Not to Multiply Without Necessity.” *Australasian Journal of Philosophy* 93:644–664. ISSN 0004-8402. doi:10.1080/00048402.2014.992447.

—. 2017. “Laws for Metaphysical Explanation.” *Philosophical Issues* 27:302–321. ISSN 1758-2237. doi:10.1111/phis.12111.

Schnieder, Benjamin. 2011. “A Logic for ‘Because’.” *The Review of Symbolic Logic* 4:445–465. ISSN 1755-0211, 1755-0203. doi:10.1017/S1755020311000104.

Williamson, Timothy. 2016. “Modal Science.” *Canadian Journal of Philosophy* 46:453–492. ISSN 0045-5091. doi:10.1080/00455091.2016.1205851.

Wilson, Jessica M. 2014. “No Work for a Theory of Grounding.” *Inquiry* 57:535–579. ISSN 0020-174X. doi:10.1080/0020174X.2014.907542.