**Grounding Ontic Structuralism**

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Abstract. A respectable assessment of priority-based Ontic Structuralism demands an elucidation of its metaphysical backbone. Here we focus on two theses that stand in need of clarification: (1) the Fundamentality Thesis states that structures are fundamental, and (2) the Priority Thesis states that these structures are prior to putative fundamental objects, if these exist. Candidate notions to illuminate (1) and (2) such as supervenience and ontological dependence failed at this task. Our purpose is to show that grounding is the best competitor to articulate (1) and (2), and regiment such theses in a desirable unified way. Our strategy is two-fold. First, we make the case that grounding does better than ontological dependence and supervenience. Second, we show that the distinction between *partial* and *full* grounds permits us to respond to an objection raised by Kerry McKenzie against the proposal of interpreting priority-based Ontic Structuralism in the idiom of metaphysical determination. Our conclusion is that priority ontic structuralists have compelling reasons for adopting a grounding-based approach.

1. **Metaphysical Credentials for Priority-Based Ontic Structuralism**

Ontic Structuralism (henceforth OS) comes in a variety of forms (for an overview, see Ladyman 1998; French 2010; Esfeld and Lam 2011; McKenzie 2017). Despite specific differences, ontic structuralist views claim to offer the most well-suited metaphysics for contemporary physics. Structuralist approaches share the doctrine that the «fundamental ontology of the world is one of structures and that objects, as commonly conceived, are at best derivative, at worst eliminable» (French 2014, p. v).

 What is a structure? Unfortunately, there is no canonical answer. As it will become clear in clarifying our aims, we do not wish to defend any candidates of fundamental structures. For our purposes, we take structures to be the kind of entities that ontic structuralists single out extensionally: extrinsic properties, relations, and symmetry groups. We add one caveat to this characterisation: structures are not objects. By ‘objects’, whatever these are according to a theory under consideration, we mean the bearers of determinate kinds of physical properties or relations. This conception of objecthood does not entail that objects are individuated by a primitive *thisness* or *haecceity*. Thus, we shall remain neutral on whether objects have haecceities. On this conception, paradigmatic examples of objects in particle physics are particles and fields. We acknowledge that this notion of objecthood might dissatisfy some ontic structuralists. However, for our aims, nothing relevant hangs on it.

 On its broadest construal, OS is «any form of structural realism based on an ontological or metaphysical thesis that inflates the ontological priority of structures and relations» (Ladyman 2009, Section 4). Accordingly, ontic structuralists are committed to the claim that structures—not objects—belong to the ontological fundamental level. As nicely put by McKenzie (2014, p. 353):

Even if there should exist a set of ‘fundamental objects’ […] it is not the case that such objects would qualify as truly fundamental. Rather, in their view, the most basic metaphysical level of the world is constituted solely by the *structures* that our best physics theories describe.

Our focus is on a *priority-based* form of Ontic Structuralism, or Priority OS—as we shall call it (the label ‘priority-based’ is from McKenzie forthcoming). Our motivation lies in the idea that Priority OS offers the broadest and, plausibly, the most defensible interpretation of OS. It is well known that *eliminative* formulations of OS (Ladyman 1998; French and Ladyman 2003; Ladyman and Ross 2007: French 2010), which hold that «structure is all there is» and admit no objects in the ontology, face a serious objection concerning the coherence of having relations (structures) without relata (objects). By contrast, Priority OS «represents a different and seemingly less extreme route to the same conclusion regarding the fundamentality of structure» (McKenzie forthcoming, p. 1) for it accepts both objects and structures in its ontology.

What is distinctive about Priority OS is the commitment to the purported ontological priority of structures over objects. The primacy of structure is typically expressed by saying that putative physical objects are dependent, in a fashion yet to be clarified, upon relevant structures. For examples, French (2010, p. 104) takes Priority OS as committed to the view that «each fundamental physical object depends on the structure to which it belongs». In a similar vein, Ladyman and Ross (2007, p. 130) say that «according to [Priority] OSR (ontic structural realism), even the identity and individuality of objects depends on the relational structure of the world».

On this interpretation, Priority OS appears to be committed to two theses, which we shall call the **Fundamentality Thesis** and the **Priority Thesis**,respectively.

**Fundamentality Thesis.** All fundamental physical entities are structures.

**Priority Thesis.** Fundamental structures are prior to putative physical objects if these exist.

The above theses are independent. One can endorse the **Fundamentality Thesis** while rejecting the **Priority Thesis**. However, as we will clarify in a moment, the overall goal of this paper is to defend a unified, and therefore methodologically appealing, interpretation of both theses in terms of the popular notion of *grounding*. So, we shall set aside the discussion of *eliminativist versions* of OS that deny the existence of objects and hold the **Fundamentality Thesis** only. Likewise, we shall not engage with *moderate versions* of OS, according to which structures and objects are ontologically on a par, or equi-fundamental (e.g. Esfeld and Lam 2008). Whether these versions of OS can be framed in the idiom of grounding is a question that we leave to a separate investigation.

The **Fundamentality Thesis** rules out that objects are fundamental entities. They do not belong, as it were, to the most basic inventory of what there is.

We can spell out the **Priority Thesis** with a metaphor. Imagine that reality is layered and has a fundamental level. We can regard the **Priority Thesis** as stating that structures are prior to objects in the sense that only structures belong to the truly fundamental level, whereas objects belong to a less fundamental one. The **Priority Thesis** also captures the idea that objects metaphysically depend, in a sense that we shall elucidate in due course, upon structures. Note that there are two ways of thinking of the priority of structures over objects: one is that the *existence* of putative fundamental physical objects (according to a theory under consideration) depends on the existence of the structures to which they belong, the other is that the *identity* of putative fundamental physical objects depends on that of the structures to which they belong. As it happens, both readings have been invoked by ontic structuralists. For now, we shall leave this distinction implicit.

Any version of Priority OS should find a clear articulation of the **Fundamentality Thesis** and the **Priority Thesis**. Our purpose is to do just that. We aim to show that grounding is the best metaphysical candidate for elucidating and regimenting the **Fundamentality Thesis** and the **Priority Thesis** in a desirable unified way. Therefore, we set out to argue that priority-based ontic structuralists ought to interpret their view in the idiom of grounding.

We proceed as follows. In the remainder of this section, we lay out some assumptions. In Section 2, we outline and defend a grounding-based version of PriorityOS. We shall call this view *Grounding OS* for short. In the same section, we show how Grounding OS successfully escapes the worries that supervenience and ontological dependence face in elucidating the relationship between structures and objects. Unfortunately, our proposal is not exempt from difficulties. In Section 3, we illustrate an objection raised by Kerry McKenzie (forthcoming) against our proposal of reformulating Priority OS in terms of grounding or other forms of metaphysical determination. In Section 4, we contend that McKenzie’s objection is non-lethal. By invoking a distinction between *full* and *partial* grounds, we show how to respond to McKenzie’s objection. In light of such a distinction, in the same section, we revise the principles that connect grounding and priority. Lastly, in Section 5, we implement the proposed apparatus into Grounding OS and offer some concluding remarks for future investigations.

Before reformulating the **Fundamentality Thesis** and the **Priority** **Thesis** in terms of grounding, we need to lay out a few preliminary remarks.

 First, it is not our aim to assess the correctness of a particular version of Priority OS. Accordingly, we ignore the question of how to incorporate Grounding OS into a specific physical theory. Our aim is different: namely, to defend grounding as the best notion for articulating the **Fundamentality Thesis** and the **Priority Thesis**.

 Second, we assume the plausibility and intelligibility of grounding. Of course, this is not to deny that grounding faces criticism on its own. Arguably, any problem with this very notion would carry over to our proposal. We simply accept this unlovely possibility. However, problems with grounding do not get Grounding OS off the table. This suffices for the purposes of this paper. It cannot be reasonably expected of us to address any metaphysical challenges that grounding faces. Our focus will be only on those that are related to Grounding OSspecifically.

Lastly, a wee note on the examples: those that we will invoke are meant to be merely illustrative. Bearing these remarks in mind, we set out to articulate and defend the adoption of Grounding OS.

1. **Grounding-based Priority Ontic Structuralism**

The concepts of fundamentality and priority enjoy a surge in popularity in contemporary metaphysics, which is shown by the blooming literature on these topics. Our suggestion is that ontic structuralists would benefit from recent metaphysical developments to clarify the backbone of Priority OS. In this spirit, we submit that *grounding* is the best candidate for articulating the **Fundamentality Thesis** and the **Priority Thesis**. Grounding OS, which is the name of the proposed grounding-based approach to Priority OS, can claim three major advantages: (i) it allows us to articulate in a desirable unified way both the **Fundamentality Thesis** and the **Priority Thesis**; (ii) it escapes the objections raised against the interpretation of the relationship between structures and objects in terms of supervenience and ontological dependence, and (iii) it secures the explanatory import that structures play in ontic structuralist approaches. We shall vindicate these merits in what follows.

The literature of grounding is vast and intricate. Here we rely on the orthodox view of grounding (e.g. Fine 2001, 2012; Schaffer 2009; Rosen 2010). Accordingly, we take that grounding is «a constitutive form of determination» (Fine 2012, p. 37). Where there is grounding, there is metaphysical determination.

On the orthodox view, grounding is irreflexive, asymmetric, and transitive.[[1]](#footnote-2) Moreover, it has an intimate connection with ‘metaphysical’ explanation: if A grounds B, then A metaphysically explains or helps explain B. Grounding explanations are ‘metaphysical’ in the sense that they involve something that determines non-causally and synchronically for the nature and/or existence of something. Grounding theorists disagree on the tightness of the link between grounding and explanation. Some say that grounding is metaphysical explanation (e.g. Dasgupta 2014; Raven 2015; Thompson 2018). Others opt for a weaker connection (e.g. Schaffer 2009). Moreover, grounding orthodoxy recognises a distinction between full and partial grounds. Such a distinction will play a crucial role in Section 5. Therefore, we will characterise it in more detail there. For now, let us say that X partially grounds Y just in case there is something else together with X such that they jointly fully ground Y (Fine 2012, p. 50; Raven 2015, p. 324). In this sense, partial grounds are completable.[[2]](#footnote-3)

Lastly, we need to acknowledge a distinction which concerns two kinds of grounding claims: we can separate between claims of the form ‘X’s existence is grounded in that of Y’ from claims of the form ‘X’s identity is grounded in that of Y’. Both readings have been suggested in the structuralist literature with respect to other notions of dependence. For example, French (2010, p. 105) invokes Lowe’s identity dependence to characterise Priority OS:[[3]](#footnote-4) «the identity of the putative objects/nodes is (asymmetrically) dependent on that of the relations of the structure». By contrast, Esfeld and Lam (2011, p. 146) take into account a form of existential dependence: «relations are ontologically primary and objects are ontologically secondary in the sense that they derive their existence from the relations in which they stand and thus from the structures they are part of». We believe that the same distinction applies to grounding claims. Of course, one might wonder how to relate the two kinds of grounding claims, and what principles govern them. Here we wish to remain neutral for we assume that both interpretations can capture the priority of structures over objects. Such a neutrality is due to two reasons. First, the task of regimenting the logic of identity and existence grounding claims would demand a separate investigation. Second, ontic structuralist approaches already differ with respect to identity and existence claims about structures and objects. We simply reformulate these claims in the context of Priority OS as grounding claims. So, we shall not adjudicate, for instance, the question of whether identity grounding claims entail existence grounding ones, although this seems quite plausible (e.g. Fine 2015).

Now let us reformulate the **Fundamentality Thesis** from the viewpoint of Grounding OS. The orthodox view offers a definition of fundamentality in terms of being ungrounded. That is, the fundamental entities are those that are not grounded in anything else. A characterisation of the fundamental in terms of ungroundedness has the virtue of adequately elucidating what the notion of fundamentality exactly amounts to (something that is largely left unexplained in standard formulations of OS). This characterisation stems directly from the standard properties of grounding relations, which are asymmetric, transitive and irreflexive, and are supposed to terminate in something un-grounded. There are two main ways in which ‘being un-grounded’ can be cashed out: ‘being well-founded’ (that is, the grounding chains terminate in an un-grounded element after a finite number of steps) and ‘being bounded from below’ (that is, there is no need for a finite number of steps between each element of the grounding chain and the *fundamentalium* that grounds it). The appeal to ungrounded entities—which ground everything else—avoids a vicious infinite regress, which is generated when everything depends upon (and explains) everything else.

We submit an interpretation of the **Fundamentality Thesis** as an **Ungroundedness Thesis**.

**Ungroundedness Thesis**. A structure is fundamental if and only if there is nothing else that grounds its identity or existence.

The **Ungroundedness Thesis** gives us a necessary and sufficient condition for the fundamentality of structures, thereby elucidating the notion of fundamentality at play in Priority OS. In the spirit of their doctrine, priority ontic structuralists would maintain that all physical fundamental entities are ungrounded structures.[[4]](#footnote-5)

Now let us ask: How does grounding elucidate the **Priority Thesis**? Our answer is that grounding is a determination relation which is precisely meant to discriminate between what is prior and what is derivative (e.g. Schaffer 2009, p. 373; Rosen 2010, p. 116; Raven 2012, p. 689; Bennett 2017, p. 40; Rabin 2018, p. 42). Such a connection is clear on the orthodox view for it endorses the following principle:

**More Fundamental Than (MFT)**: if X partially or fully grounds Y, then X is more fundamental than Y.

In **MFT**, grounding is *strict*: it does not allow for one thing to ground itself. We take to be uncontroversial that **MFT** so understood yields ontological priority: if X is more fundamental than Y, then X is ontologically prior to Y. We also take that **MFT** holds for existential grounding claims and identity ones equivalently (In Section 5, we shall consider more fine-grained versions of **MFT**). Putting these pieces together, we can interpret the **Priority Thesis** as a **Grounding Thesis**, which we formulate below.

**Grounding Thesis**. The existence or identity of each putative fundamental physical object is partially or fully grounded in that of some fundamental structure.

Given **MFT**, the **Grounding Thesis** tells us that the structures that ground, either partially or fully, the identity or existence of putative objects are more fundamental than the latter. Therefore, the **Grounding Thesis** allows us to recover the priority of structures over the physical objects that are posited by a physical theory under scrutiny.

A first important advantage emerges. By adopting Grounding OS, we can feed two birds with one scone: we can articulate the **Fundamentality Thesis** and the **Priority Thesis** in a unified way as the **Ungroundedness Thesis** and the **Grounding** **Thesis**, respectively.

If we are willing to invoke grounding to elucidate Priority OS, we should enjoy the full package deal of its benefits. The second merit of Grounding OS concerns the link between grounding and explanation. This connection permits us to safeguard the explanatory priority of structures in accounting for derivative physical objects—objects are explanatorily dependent on structures (e.g. French 2014, pp. 165–167). If structures ground physical objects, and if *groundees* (what does the grounding work) explain or help explain what is grounded, then structures explain or help explain physical objects. Of course, the complete story of how to relate grounding with explanation is more complicated than this. However, it is not our aim to fill in the details. This would be the task for a different investigation.

The third merit of Grounding OS is that it escapes the objections that two metaphysical competitors—supervenience and ontological dependence face.

Let us consider supervenience first. Supervenience is a relation of necessary covariation: if A supervenes on B, then there cannot be an A-difference without a B-difference. (for a general overview, see McLaughlin and Bennett 2018). Ladyman and Ross interpret OS as the view that the world has «an objective modal structure that is ontologically fundamental, in the sense of not supervening on the intrinsic properties of a set of individuals» (2007, p. 130). The problem is that supervenience is too coarse-grained for capturing the priority of structures over objects, and it does not guarantee an explanatory connection between them. Supervenience tracks only a modal covariation between certain things, thereby leaving us in the dark about why it holds. For example, McKenzie (2014, p.357) argues that:

Supervenience is not at all *explanatory* of any relationship between the sub- and supervenient relata; it is often regarded as at best an indication that it is worth *looking* for an explanation of the evident connection between them, while not explanatory of it.[[5]](#footnote-6)

In contrast, grounding has a constitutive link with both metaphysical explanation—which secures that objects are explanatorily dependent on structures—and priority, which we specified in terms of **MFT**. The very idea of grounding is motivated, at least partially, by the observation that this notion underlies a variety of claims where something holds because or in virtue of something else (e.g. Rosen 2010, Fine 2012).

Now let us consider ontological dependence. Ontological dependence captures a variety of relations of non-self-sufficiency. Schematically, we could say that A ontologically depends upon B if necessarily A exists only if B does.[[6]](#footnote-7) French invokes specific forms of ontological dependence to formulate Priority OS explicitly. For example, he writes (2010, p. 192):

I shall take as a core feature of [Priority] OSR the claim that the putative ‘objects’ are dependent in some manner upon the relevant relations (and hence these putative objects can be reconceptualised as mere nodes in the relevant structure). We can express this in terms of a form of […] (ODSphys) Each fundamental physical object depends on the structure to which it belongs.

In a similar vein, McKenzie (2014) explores a reformulation of Priority OS in terms of the Finean notion of essential dependence (Fine 1994, 1995).

In more recent work, however, McKenzie revises her view and argues that ontological dependence does not ensure determination. What grounds this worry is the possibility of dependence without determination (McKenzie forthcoming, pp. 10–11). As an example, McKenzie considers the possible entanglement relation between two electrons. If we assume, quite plausibly, that relations cannot exist without *relata*, then this seems to be a case where the entanglement relation would be dependent on the two electrons, but it would be incorrect to argue that the electrons (and their properties) determine the entanglement relation. To give another example, one might think that particles are dependent on spacetime symmetries without the latter determining the former. We side with McKenzie in thinking that priority ontic structuralists ought to agree that there may be cases of ontological dependence in the absence of determination. Therefore, we claim that this possibility should prompt them to favour a different notion for articulating the **Priority Thesis**.

Grounding blocks the problematic possibility of dependence without determination. Recall that grounding *is* a constitutive form of determination or, as Fine puts it, «determinative connection» (2012, p. 37). Therefore, Grounding OS is preferable than Priority OS in the idiom of ontological dependence.

To recap, grounding brings priority ontic structuralists three major advantages: (i) it permits them to articulate in a unified way the **Priority Thesis** and **Fundamentality Thesis** in terms of the **Grounding Thesis** and the **Ungroundedness Thesis**; (ii) the intimate tie between grounding and explanation shields the claim that objects are explanatorily dependent upon structures; and (iii) the objections against Priority OS reformulated in terms of supervenience and ontological dependence can be resisted straightforwardly. Therefore, grounding appears to be a better candidate in the party of metaphysical dependencies for making sense of the metaphysical commitments of Priority OS.

Unfortunately, our proposal is not immune to objections. A pressing one, which threatens the prospects of Grounding OS severely, has been recently raised by McKenzie (forthcoming). But we are convinced that this objection can be resisted. We devote the next section to illustrate McKenzie’s objection. In section 4, we show how to escape it.

1. **McKenzie vs. the Priority Thesis**

A concise way to reconstruct McKenzie’s objection (forthcoming, pp. 19–20) is as follows. Grounding and other metaphysical determination relations must respect the following entailment principle (**EP**), which is standardly associated with them (e.g. Rosen 2010, p. 118; the variables stand for suitable entities):

**EP.** If *p* metaphysically determines *q*, then *p* entails *q*.

For reasons that we will present below, **EP** is not satisfied by putative fundamental structures and objects according to our best science. Said differently, it is not the case that putative fundamental structures (or facts about putative fundamental structures) entail putative fundamental physical objects (or fact about putative fundamental physical objects). Therefore, grounding fails to secure the priority of structures over objects. McKenzie concludes that «priority-based OSR [i.e. Ontic Structural Realism]—framed as it ought to be—in the idiom of determination must be regarded unfounded» (forthcoming, p. 19). This upshot would be unwelcoming for we argued that grounding is the best candidate for articulating the **Fundamentality Thesis** and the **Priority Thesis**. The stakes are high. So, let us unpack McKenzie’s objection.

 To begin with, McKenzie articulates the objection against metaphysical determination within the context of quantum field theory (QFT). Accordingly, McKenzie takes the fundamental structures to be the symmetry groups of QFT, such as the Poincaré Group, and objects to be ‘fundamental’ kinds such as boson kinds and fermion kinds.[[7]](#footnote-8) However, it is worth noting that McKenzie’s objection clearly generalises: if there is no entailment between p and q, then it is not the case that p metaphysically determines q, irrespectively of which entities replace p and q. On McKenzie’s view, Grounding OS (or any version of Priority OS in the idiom of determination) should preserve the truth of the Grounding Claim (or the truth of the corresponding determination claim if this is not grounding).

*Grounding Claim*: fundamental symmetry groups ground fundamental kinds.

Here troubles find us. The Grounding Claim is not true, according to QFT. To be more precise, McKenzie contends that **EP** is respected for gauge symmetry groups and kinds of bosons. Specific local gauge symmetries uniquely entail the kinds of bosons that there will be, their specific integer spin and that they are massless (in the case of unbroken symmetries). It is therefore correct to claim that fundamental gauge symmetries ground boson kinds (McKenzie forthcoming, pp. 17–18). But **EP** is not preserved in the case of fermion kinds: the symmetry groups do not entail «which kinds of fermions we can expect to be instantiated» because, unlike boson kinds, their determinate kind properties are not «similarly uniquely determined» (McKenzie forthcoming, pp. 18). For example, the relevant symmetry groups do not entail the determinate masses of fermions that we can expect to find in nature. McKenzie stresses this point: «nor does the symmetry determine for us precisely how many kinds of fermions we can expect to find in nature» (ibid.). Therefore, it is not the case that fundamental symmetry groups entail fermion kinds. Since **EP** for these entities is false, the associated Grounding Claim is also false: it is not the case that fundamental symmetry groups ground fermion kinds. As summarised by McKenzie (2018, p. 19):

[…] There is seemingly nothing further in the logic of the situation that entails, given a specific symmetry, what the associated fermionic kind content is, it follows from this that there cannot be determination in any more discerning sense either.

If McKenzie’s objection is sound, then Grounding OS is in great peril. Given **MFT**,symmetry groups are more fundamental than fermion kinds if the former ground the latter. But if the *Grounding Claim* for fundamental symmetry groups and fermions kinds is false, then, *contra* priority ontic structuralists, it is not the case that these symmetry groups are more fundamental than fermion kinds.

Worse yet, if we accept **EP**, and if symmetry groups do not entail fermion kinds, then we cannot say that the symmetry groups ground fermion kinds. The most problematic consequence is that the **Grounding Thesis** would turn out to be false: it would not be the case that fundamental structures (symmetry groups) ground putative ‘fundamental’ objects (fermion kinds). Fairly obviously, this result does not fare well with our claim that grounding is the best way to formulate the priority of structures over objects.

 McKenzie’s objection poses a serious threat for priority-based versions of OS. It is worth noting, however, that her argument does not target the **Ungroundedness Thesis.** The claim that symmetry groups do not ground fermions kind does not entail that structures are not ungrounded, i.e. fundamental in an ‘absolute’ sense. Therefore, even if McKenzie’s objection were sound, it would be still possible to maintain that symmetry groups are not grounded in further entities.

In the next section, we defend the priority of structures over objects in terms of grounding from McKenzie’s objection, thereby saving the tenability of Grounding OS as captured by both the **Grounding Thesis** and the **Ungroundedness Thesis**.

1. **Priority Vindicated: How to Resist McKenzie’s Objection**

While we agree with McKenzie in thinking that **EP** is not true for the case of symmetry groups and fermion kinds, we are not persuaded that giving up grounding is the remedy. Before defending our favourite strategy to resist McKenzie’s objection, there are two other options that are worthy of attention. However, as we will explain, these suffer some problems.

The first option is to argue that QFT is a problematic test for **EP**. Quite likely, QFT will evolve and its current framework will not be truly fundamental. The arguer can contend that even if symmetry groups do not ground fermion kinds, the former will be replaced by more fundamental structures. McKenzie (forthcoming, p. 20) concedes this point but thinks that the plausibility of Priority OS should do be justified with respect to our present-day science. So, the fact that this view cannot be established now represents a persuasive reason against it. Like McKenzie, we do not think that this is the best strategy for defending Grounding OS.

Another option is to reject **EP** as a way for establishing the priority of structures. Recall that McKenzie’s objection rests on the failure of **EP** for symmetry groups and fermion kinds. Accordingly, if it is false that symmetry groups entail fermion kinds, then it is also false that symmetry groups ground fermion kinds. **EP** is weighty but not sacred. Of course, its rejection should be justified. One way to do so would be to argue that **EP** does not hold for grounding. Therefore, it would be a mistake to assess the prospects of Grounding OS by appealing to **EP**. A failure of **EP**, on this approach, would not represent a reason for rejecting Priority OS in the idiom of grounding.

In the literature, objections against **EP** take the form of counterexamples (for reasons of space, we cannot reconstruct these counterexamples here. For a more detailed treatment, see Leuenberger 2014 and Skiles 2015). Counterexamples to **EP** score some points against the assumption that this principle is wholly uncontroversial (cf. McKenzie forthcoming, p. 18). However, instances in which **EP** fails do not automatically establish that **EP** should be abandoned *tout court*. Instead, they only show that a *necessitarian* reading of **EP** is false: it is not the case that if *p* metaphysically determines *q*, then *necessarily* *p* entails *q*. This result is important on its own for many take grounding to be associated with a necessitarian version of **EP**. But it does not allow us to escape McKenzie’s objection. What threatens the priority of symmetry groups over fermion kinds is not the modal strength of **EP**. Rather it is the fact that there is nothing in the symmetry group alone that entails the determinate associated fermionic content (McKenzie forthcoming, p. 19). A better strategy is needed.

 Here is our proposal. To resist McKenzie’s objection, we draw attention to an ambiguity in interpreting **EP** and introduce a distinction which disentangles it. This ambiguity concerns two ways the entailment in **EP** can be read, which we formulate below. These two ways reflect, as it were, a canonical distinction between *partial* and *full* grounds (Fine 2012, p. 50; see Section 2). We shall call these readings **Full EP** and **Partial EP**, respectively. Our claim is that McKenzie’s objection targets only **Full EP**. By contrast, the case of symmetry groups and fermion kinds does not violate **Partial EP**. As we will explain, the grounding OS-ists can secure the priority of symmetry groups over fermion kinds in terms of partial grounding, thereby escaping McKenzie’s objection.

Let us begin by clarifying the distinction between partial and full grounds, which is orthodoxy amongst grounding theorists. An analogy with explanation is helpful to illustrate it. As we can distinguish between a full explanation from its contributing parts, we can separate between full and partial grounds, which are akin to the contributory parts of a full explanation. For instance, take the conjunction A&B. Each of A and B is a partial ground of A&B. And each of A and B contributes to a complete explanation of A&B. But typically, neither A nor B on its own suffices to fully ground or fully explain A&B (Fine 2012, p. 50). We can define the notion of partial ground in terms of full ground as follows, where 𐌲 is a possibly empty set (cf. Fine 2012, p. 50; Raven 2015, p. 324).

*Completability*: *p* partially grounds *q* if and only if there is a set 𐌲that includes *p* such that 𐌲 fully grounds *q.*

*Completability* says that something is a partial ground just in case «there is something else together with which it is jointly a full ground» (Leuenberger 2019, p. 3).

Once the full/partial ground distinction is acknowledged, we can distinguish between **Full EP** and **Partial EP**.

**Full EP**. If *p* fully grounds *q*, then *p* entails *q*.

**Partial EP**. If *p* partially grounds *q*, then *p* together with something else or on its own entails *q*.

Since partial grounds do not typically entail what is grounded, one might wonder whether the disjunctive consequent in **Partial EP** is needed. For example, A partially grounds the conjunction A&B, but typically A on its own does not entail A&B. However, we acknowledge that some partial grounds can entail on their own what is grounded. To use Fine’s example, A and B are the partial grounds of A∨B, but each of A and B is also a full ground of A∨B. Whenever A partially grounds A∨B, A on its own entails A∨B (Fine 2012, p. 50). For this reason, we need to adopt a disjunctive formulation in the consequent of **Partial EP**.

Our claim is that McKenzie’s objection against Priority OS in the idiom of determination aims at **Full EP** but overlooks the possibility of capturing the priority of structures in terms of **Partial EP**.McKenzie claims that symmetries alone do not entail the fermion kinds that are realised in nature. Consequently, she argues, symmetries do not ground fermion kinds (forthcoming, p. 20). We contend that the inference from the failure of entailment between symmetries and fermion kinds to the failure of grounding between them shows *only* the falsity of **Full EP**. That is, if symmetries alone do not entail fermion kinds, then the right conclusion to draw is that symmetries do not fully ground fermion kinds. This upshot leaves open the possibility that symmetries *partially* ground fermion kinds. To establish that symmetries do not even partially ground fermion kinds, one needs to show that symmetries together with something else do not entail fermion kinds (we shall discuss this issue in a moment). However, McKenzie’s objection does not show the failure of **Partial EP**. Thus, the Grounding OS-ist can argue that we should understand the determinative relation between symmetries and fermion kinds in terms of partial grounding.

Is it plausible to maintain that symmetry structures partially ground kinds of fermions? We think so. Even if the relevant symmetries do not determine on their own the determinate properties of kinds of fermions, we know that the latter are constrained significantly by the symmetries. For example, we know that the determinate properties of fermion kinds should be consistent with the possibilities admitted by the representations of the symmetry group in question. Moreover, symmetry considerations reveal that the fundamentality of specific structures and their associated laws impose a limit on the number of fermion kinds that can co-exist consistently. To use McKenzie’s example, if the SU(3) gauge symmetry is fundamental, then there cannot be more than sixteen kinds of fermions for the theory to be still valid up to arbitrarily high energy scales. This is to say that if there are more than sixteen fermion kinds, the consistency of the theory in the limit of infinite energy is lost. More generally, it can be shown that symmetry considerations support what McKenzie (2016) calls the ‘Goldilocks Principle’ for fundamental kinds:

Whatever the set of fundamental kinds is, it will take the form {B*1*, …B*N*; F*1*, … F*M*} for some *N* > 0 and with an upper bound on *M*, and with the values of *M* and *N* connected via symmetry considerations, where the B*i* denote the bosonic and the F*i* fermionic kind. (McKenzie forthcoming, p. 18)

It thus appears that fundamental structures determine at least some relevant features and facts about what kinds of fermions we can find in nature. On Grounding OS, such a determination is captured by the claim that structure partially grounds fermion kinds. Someone might quibble that determination by constraint is not the right kind of determination. But it seems that this form of determination does not infringe the generic entailment principle **EP** for metaphysical determination. If a symmetry constrains at least partially the kinds of particles that we can expect to find in nature, then the symmetry entails certain features and facts about these particle kinds. For example, that there is only a certain number of them, and that they should correspond to representations admitted by the theory under consideration. As such, we do not find this line of resisting our suggestion—namely that symmetry structures partially ground fermion kinds—particularly convincing.

To vindicate the priority of symmetry structures over fermion kinds, we need to recall that partial grounding is sufficient for establishing that symmetries are more fundamental than fermion kinds. We have already introduced a principle that links partial grounding with priority in Section 2: **MFT**, which states that if X partially or fully grounds Y, then X is more fundamental than Y. We take that it is uncontroversial to hold that if X is more fundamental than Y, then X is ontologically prior to Y. Thus, Grounding OS-ists can simply appeal to **MFT** for securing the priority of symmetries over fermion kinds. Accordingly, if symmetries partially ground fermion kinds, then symmetries are more fundamental, and hence prior to, fermion kinds.

It is important to stress that a failure of **Full EP** does not entail a failure of **Partial EP**. While symmetries on their own fail to fully ground fermion kinds, this does not rule out the possibility that symmetries together with something else—as expressed by **Partial EP**—fully ground fermion kinds. The immediate question is: what is the extra element that together with symmetry structures fully grounds fermion kinds?

Like McKenzie, we maintain that our present understanding of QFT does not permit us to answer this question. What the extra element is, which we can call *r* as a placeholder, will be settled by experiment. To be clear, this limitation does not threaten our proposal because we can establish the priority of structures over fermion kinds in terms of partial grounding by means of **MFT**. So, the fact that *here and now* we are unable to specify the full grounds of fermion kinds does not entail the falsity of the **Grounding Thesis**. However, there are two possibilities (out of three) that potentially undermine Priority OS. Unfortunately, we can only speculate in broad strokes about them.

The first possibility is that r is a structure or a structural element, one which together with the relevant symmetry groups entails, and allows us to explain, the specific determinate properties of fermion kinds that are in fact instantiated in nature. If this were the case, then Grounding OS would be home and dry: the full ground of fermion kinds would consist of structures only (namely, symmetry groups and r). Perhaps r is a yet to be discovered structure or some otherwise inherently structural feature of our universe.

The second possibility is that r is an object or a non-structural, object-like element. Of course, this would be bad news for Priority OS. If r is an object, then the fundamental physical ontology does not comprise just structures. The full ground of fermion kinds would contain structural and non-structural elements. Thus, it would be incorrect to claim that structures are prior to putative fundamental physical objects. However, Grounding OS-ists could insist that if we endorse the **Grounding Thesis**, then r should be further grounded in some more fundamental structure. In fact, this is precisely what the **Grounding Thesis** states: each putative fundamental physical object is grounded in some fundamental structure. So, if r is an object, and if the **Grounding Thesis** is true, then r is grounded in some fundamental structure. This strategy would allow Grounding OS-ists to recover the view that there are no fundamental objects. Albeit suggestive, this argument implies that we have “armchair” considerations for thinking that the nature of r is structural. But arguably, the nature of r should not be adjudicated a priori. A preferable option, assuming that r is indeed an object, is to embrace a moderate version of ontic structuralism (Esfeld and Lam 2008). On this view, the fundamental ontological constituents of our reality are structures and objects. Since this view assigns the fundamental status to some physical objects, moderate ontic structuralism must be distinguished from Grounding OS. However, this view is still a form of ontic structuralism. As such, the possibility that r is an object does not represent a reason to renounce the idea that structures are fundamental. It is worth repeating that even if r is an object, symmetry groups would be more fundamental than fermion kinds. As we argued above, **MFT** ensures that symmetries are more fundamental than fermion kinds even if symmetries only partially ground fermion kinds.

The third possibility is that r is neither a structure nor an object. Perhaps r is an entity that belongs to a category that is reducible to neither structures nor objects, which nonetheless—together with the relevant symmetry structures—permits the derivation of the determinate properties of fermion kinds that are realised in nature.[[8]](#footnote-9) If so, symmetry groups would be more fundamental than fermion kinds as they partially ground them, but the emerging view would be a form of impure or weak OS. The fundamental ontology would consist of structures and something else non-structural as well as non-objectual. This possibility does not undermine our claim that structures are more fundamental than fermion kinds by virtue of partially ground them. But it does undermine a pure or strong form of OS, according to which the fundamental entities are all and only structures.

More needs to be said about each of the above possibilities. However, recall that our purpose is to vindicate the priority of symmetry structures over fermion kinds in terms of grounding. The previous considerations should convey the underlying idea that partial grounding is sufficient to accomplish our aim. In order to establish that symmetries do not even partially ground fermion kinds, one must show that symmetries taken together with *r* do not entail fermion kinds. But McKenzie’s objection does not establish this point. Rather McKenzie’s point is that current physics does not allow us to identify what *r* is. Yet, as we argued, this limitation does not undermine the priority of structures over fermion kinds.

McKenzie could protest that securing the priority of symmetries in this way is too weak. For example, she claims that we should not allow «structure to be more fundamental than the actual-world objects if the former merely determine the possibilities for the latter and not what they in fact are» (forthcoming, p. 20). However, the claim that symmetries partially ground fermion kinds should not be confused with the different claim that symmetries partially ground only possible fermion kinds. If symmetries (and structures, more generally) partially ground fermion kinds and other objects, then they do play a role in (partially) determining by constraint actual as well as possible fermion kinds. For example, the fundamentality of a certain symmetry grounds the limit of fermion kinds admitted by the theory. Both actual and possible fermion kinds are constrained by such a limit. Said differently, the fundamentality of a specific symmetry allows us to explain why only a certain number of fermion kinds can co-exist consistently. Such an explanation applies to both actual as well as possible fermion kinds. So, it appears that the claim that symmetries partially ground fermion kinds concerns both actual fermion kinds as well as possible ones.

 By placing the full/partial ground distinction under the spotlight, we reveal a way to resist McKenzie’s objection. To recap, by considering the distinction between partial and full grounds, we put forward two readings of **EP** and argued that McKenzie’s objection threatens only what we called **Full EP**. By appealing to **MFT**, which we introduced in Section 2, we showed that partial grounding suffices to establish the priority of symmetry groups over fermion kinds. Overall, Grounding OS can preserve the desired priority of structures over objects.

1. **Taking Stock**

So far, our discussion has been focused primarily on articulating and defending an interpretation of the **Priority Thesis** *qua* a**Grounding Thesis**. Now it is time to put the pieces together: we use the grounding machinery to cash out Priority OS as a grounding view. To accomplish this aim, we reformulate the links between grounding, priority, and fundamentality.

To start, recall that we can distinguish between identity grounding claims and existential ones (Section 2). By applying the full/partial distinction to the distinction between identity and existence grounding claims, we obtain a more fine-grained characterisation of the relevant dependence at play in Grounding OS:

(1) **Full Identity/Existence Grounding–Priority Link**: if X fully grounds Y for its identity/existence, then X’s identity/existence is prior to that of Y.

(2) **Partial Identity/Existence Grounding – Priority Link**: if X partially grounds Y for its identity/existence, then X’s identity/existence is prior to that of Y.

The principles (1) and (2) connect identity and existence grounding claims with corresponding priority claims. They are specifications of the more general **MFT** principle (Section 2), which states that if X grounds Y, then X is more fundamental than Y.

As we illustrated in Section 1, Priority OS is committed to both the **Priority Thesis** and the **Fundamentality Thesis**. In Section 2, we argued that such theses could be reformulated as the **Grounding Thesis** and **Ungroundedness Thesis**, respectively. Principles (1) and (2) allow us to characterise the **Grounding Thesis** in a more fine-grained way.

On its broadest construal, Priority OS holds that both the existence and the identity of objects are derivative with respect to that of the structures to which they belong. Objects can be regarded as nodes or *relata* that emerge from the relevant structures or relations. For example, French (2010, p. 105) observes that priority-based ontic structuralists could maintain that «the identity of the putative objects is asymmetrically dependent on that of the relations of the structures». But they could also maintain that «fundamental physical objects depend for their existences on the relations of the structures» (*ibid*.) If we translate these claims in grounding terms, we obtain the following thesis:

(a) The identity or existence of putative fundamental physical objects is fully grounded in that of structures.

Our grounding apparatus permits us to understand (a) in accordance with **Full Identity/Existence Grounding–Priority Link**. However, we must recall that McKenzie’s objection (Section 3) undermines the truth of (a), where the **Grounding Thesis** is at stake: according to our best physics, it does not seem that structures *fully ground* putative fundamental objects such as fermions. As we argued in the previous section, however, we can preserve the priority of structures over objects in terms of partial grounding. Thus, Priority OS-ists should interpret (a) in terms of partial grounding, which yields the following thesis:

(b) The identity or existence of putative fundamental physical objects is partially grounded in that of structures.

According to our proposal, the priority of structures in (b) is best expressed by the **Partial Identity/Existence Grounding–Priority Link**. On this interpretation, (b) escapes McKenzie’s objection—without renouncing the **Grounding Thesis**.

In sum, principles (1) and (2) provide us with a fine-grained analysis of grounding and its relationship with fundamentality and priority. By invoking these principles, we can put forward a useful reinterpretation of Priority OS as Grounding OS. The take-home message of our proposal is that grounding brings priority ontic structuralists three main benefits:

1. It escapes the shortcomings that supervenience and ontological dependence face in illuminating the priority of structures over objects (Section 2).
2. It allows us to articulate the thesis that structures are fundamental and prior to objects in a unified way (Section 3).
3. It offers priority ontic structuralists a way to resist McKenzie’s objection that symmetry groups cannot be said to be prior to fermion kinds by means of partial grounding (Section 4).

These advantages, we contend, the priority ontic structuralists compelling reasons to adopt Grounding OS. To put it differently, Priority OS *ought to be understood* asGrounding OS. Crucially, the advantages of our proposal have first of all an explanatory import: the grounding principles (1) and (2) fulfil the task of elucidating the metaphysical commitments of Priority OS and—given the intimate connection between grounding and metaphysical explanation—offer a more in-depth insight into the priority and dependency relations between structures and objects.

We conclude with a note for future work. Our discussion has neglected the question of whether principles (1) and (2), or suitable modifications of them, can be applied to other forms of OS—such as Eliminative OS and Moderate OS. That is, we did not answer the question of whether Eliminative OS and Moderate OS ought to be understood as grounding views. If the answer were positive, an original grounding taxonomy of the main OS approaches would emerge. Such a taxonomy would express and classify the metaphysical commitments of ontic structuralist of various stripes as grounding theses in a unified way. However, we leave the task of articulating and evaluating grounding versions of Eliminative OS and Moderate OS to another investigation. More modestly, in this paper, we aimed to show that the theoretical merits of reformulating Priority OS in the idiom of grounding. If we are right, priority ontic structuralists have a compelling justification for adopting the proposed approach.

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1. Each of these formal features has been challenged. We will not attempt to settle the question of whether grounding is formally unitary. For example, Jenkins (2011) challenges irreflexivity. Wilson (2014) calls asymmetry into question. Schaffer (2012) offers a counterexample to the transitivity of grounding. For a more general overview of how different formal properties of grounding can be defended, see Bliss and Priest (2018). [↑](#footnote-ref-2)
2. Against the completability of partial grounds, see Leuenberger (2019). For our purposes, it suffices to accept the distinction between partial and full grounds. Whether the completablity principle is false does not concern us for its possible falsity does not undermine the distinction. [↑](#footnote-ref-3)
3. French defines Priority OS as ‘Weak Structural Realism’, but it is plausible to identify these two views. [↑](#footnote-ref-4)
4. Being *un*grounded must not be confused with being *zero*-grounded. The latter case permits that something is grounded in zero elements. The former, which is our target case, implies that there is no number of elements (not even zero) that grounds which that is ungrounded. For more on the distinction between these two notions, see Fine (2012, pp. 47–48) [↑](#footnote-ref-5)
5. Wolff (2012) raises a different objection to supervenience, focused on the link between reduction and supervenience: «for A to reduce to B, A has to supervene on B. For A to supervene on B, there *cannot* be a change in A without a change in B» (ibid. p. 611). However, the modal force carried by supervenience is too weak to establish such a reduction claim; moreover, counterexamples from physics shows that supervenience does not hold in the case of representations and symmetry groups. Consequently, representations do not reduce to symmetry groups. [↑](#footnote-ref-6)
6. This schema expresses a form of modal-existential dependence (Lowe 1994). However, other interpretations of dependence have been formulated. Among them, we can find essential dependence (Fine 1994; 1995) and identity dependence (Lowe 1994; Tahko and Lowe 2015). For a more comprehensive analysis of the varieties of dependence, see Tahko and Lowe (2015) and Koslicki (2012). [↑](#footnote-ref-7)
7. Here talk of fundamental kinds is not to be understood in terms of these kinds being ungrounded. Rather it is best regarded as pointing out the most basic kinds that we find at the fundamental level and that constitute the less basic ones. [↑](#footnote-ref-8)
8. Maybe *r* belongs to the category of *activities* or *processes* if these are indeed irreducible to either objects or structures. [↑](#footnote-ref-9)