Concerning the Levels of the Empirical Sciences

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Abstract

It is the aim of this paper to develop and defend an interpretation of level of scientific discipline within the truth-maker framework. In particular, I exploit the mereological relation of proper parthood, which is integral to truth-maker semantics, in order to provide an account of scientific level.

Introduction

The philosophy of science is replete with discussions of level. Arguably, physics occupies a lower level than chemistry, which occupies a lower level than biology, which occupies a lower level than ecology, etc.. Practicing scientists are also prone to describing their respective disciplines in terms of level; it is not uncommon to encounter assertions like 'This problem ought to be accommodated at the level of quantum mechanics, rather than chemistry.'[1] But while there is some (if far from universal) measure of agreement over the presence of scientific level—and even some (if far from universal) measure of agreement over what the levels actually are—there is currently no consensus on what a scientific level itself consists of. While many maintain the physics occurs at a more fundamental level than ecology does, it is far from clear what makes this the case: what it is in virtue of that one scientific discipline occurs at a higher level than another.

One type of characterization is epistemic. Perhaps we ought to understand what a scientific level is in terms of what it required to understand that science. The reason biology is at a higher level than chemistry, some might reasonably maintain, is that an exhaustive understanding of biology requires at least some understanding of chemistry,

[1]One example, chosen effectively at random, is the following: "Nowadays, both theoretical and experimental investigations have presented a conclusion that the evanescent modes of the electromagnetic field can superluminally propagate. *At the level of* quantum mechanics, via tunneling analogy the superluminal propagation of evanescent modes has been described as the quantum tunneling behavior of photons, which implies that the superluminality of evanescent modes is due to a quantum effect. In this paper *at the level of* quantum field theory, we will further show that the superluminality of evanescent modes is due to a purely quantum effect, and clarify some misunderstandings on the physical properties of evanescent modes." (Wang, Xiong and He, 2008, pg. 319—emphasis mine).

while it is possible to understand chemistry without any comprehension of biology at all. More generally, there is a perfectly intelligible interpretation according to which discipline D occupies a lower level than discipline D' just in case an understanding of D' requires an understanding of D, but an understanding of D does not require an understanding of D'.

But there is another notion of scientific level—one that finds its home in metaphysics, rather than epistemology. On this conception, the reason that biology occurs at a higher level than chemistry has nothing whatsoever to do with our epistemic access to biological and chemical facts. Even if these disciplines were to lie far beyond our epistemic reach, chemistry would remain more fundamental than biology. On this conception, there is a worldly relation which obtains between the disciplines, and it is because the disciplines stand in this relation that some are at different levels from others. An interpretation of the levels of science, on this approach, amounts to an account of what this worldly relation is.

Some might be tempted to account for this relation in terms of grounding—a primitive relation of metaphysical dependence that has garnered substantial interest in recent years.[2] Perhaps the reason biology is at a higher level than chemistry is that every biological fact is grounded in chemical facts, and perhaps the reason physics is not at a higher level than economics is that there are at least some physical facts which are not grounded in economic facts. I myself am skeptical of this approach. Of course, one may freely refer to the levels of science as 'grounding,' but this merely affixes a name to the mystery; it does not render it unmysterious. And the claim that grounding is primitive rings of defeatism—amounting to the admission that there is no reductive analysis of this phenomenon to be found.

It is my aim to provide such an analysis: to uncover necessary and sufficient conditions for one scientific discipline to occupy a higher level than another. The approach I adopt exploits the theoretical resources of truth-maker semantics—a burgeoning field with applications that span the philosophy of language, metaphysics, and beyond.[3] Roughly, it is my claim that the states of affairs which make it the case that objects satisfy higher-level predicates are composed of states of affairs which make it the case that objects satisfy lower-level predicates. For example, it may be that states of affairs concerning 'is carbon-dioxide' are composed of states of affairs concerning 'is carbon' and 'is oxygen.' My approach thus relies upon the notion of proper-parthood inherent within this semantic framework in order to account for scientific level. While some background in truth-maker semantics will facilitate an understanding of the account I provide, it is not strictly needed for what I claim here,

[2]The literature on ground has quickly grown too substantial to adequately address in a footnote. Early converts include, e.g., Schaffer (2009, 2010); Fine (2012*b*,*c*). Those who advocate interpretations of scientific level along these lines include, e.g., Dasgupta (2014); Schaffer (2017). However, for some detractors to this approach, see, e.g., Della Rocca (2014); Wilson (2014).

[3]For an overview of truth-maker semantics, see **?**. For uses of truth-maker semantics in this area, see deRosset (2017); Elgin (2020). I am very sympathetic to deRosset's claim; I take it to be the closest in the literature to my own. One point of difference is that, while he is concerned with the truth-maker approach as it concerns levels of *facts*, I am concerned with its application to *disciplines*. Thus, while his approach may determine that the chemical fact that water is a compound is grounded in physical facts, I am concerned with what it takes for chemistry to be at a higher level than physics.

and I have attempted (albeit not entirely successfully) to restrict myself to an informal presentation where possible.

Before commencing with the discussion of scientific level, two points bear on limitations of this paper. First, as with many interpretive debates within our discipline, I do not assume that there is a unique correct resolution.[4] Perhaps multiple theories of scientific level are adequate. What I offer is *an* interpretation of level, rather than *the* interpretation of level. To that end, I proceed by arguing that my interpretation satisfies our theoretical demands, not by claiming that it is preferable to competing views. Second, this paper is strictly intended to remain agnostic about which disciplines occupy which levels—and, indeed, on whether the disciplines are leveled at all. Although I occasionally appeal to intuitions about the levels of science, and although I am personally susceptible to the view that there are levels of empirical science, it is perfectly compatible with what I have to say that there are not. In this case, I provide conditions which fail to obtain; the reason that the sciences are unleveled is that they do not stand in the relation I articulate. This puts my approach at odds with others in the literature. While those who debate the interpretation of physicalism often take no stand on whether physicalism is true, those who debate the interpretation of scientific level regularly express commitments to the levels of science.[5] In contrast, I restrict myself to the interpretive question—I am concerned with what a level of science is, not with what the levels of science are.

Theoretical Desiderata

I maintain that the following are theoretical desiderata for any interpretation of scientific level:

1. To form a strict partial ordering over the disciplines.
2. To account for the reductive component of level.
3. To allow for properties to be multiply realized.
4. To remain agnostic about what the levels of science are.
5. To permit crossover in subject-matter between levels of discipline.

Let us take these in turn.

1. To Form A Strict Partial Ordering Over The Disciplines

A (binary) relation is a strict partial ordering just in case it is irreflexive, asymmetric and transitive. By claiming that an adequate account of level forms such an ordering, I thus maintain that the following obtains:

[4]For a discussion of this point as it pertains to the interpretation of physicalism, see Crane and Mellor (1990).

[5]See, most canonically, Oppenheim and Putnam (1958); Fodor (1974).

i) No discipline is at a higher level than itself.
ii) If discipline D_1 is at a higher level than discipline D_2, then discipline D_2 is not at a higher level than discipline D_1.
iii) If discipline D_1 is at a higher level than discipline D_2 and discipline D_2 is at a higher level than discipline D_3, then discipline D_1 is at a higher level than discipline D_3.

I have nothing substantial in support of this desideratum to offer.[6] Its best defense is that it is overwhelmingly obvious that it is true. The intuition that sciences are not at higher levels than themselves (and that the other corresponding claims hold) runs deep. To my mind, the satisfaction of this condition is not merely desirable, but compulsory. Any account which fails to form a strict partial ordering over the disciplines ought to be abandoned, regardless of whatever other advantages it might have.

2. To Account For The Reductive Component Of Level

The notion of level seems to be inextricably tied to that of reduction.[7] If thermodynamics occurs at a higher level than statistical mechanics, it seems no accident that thermodynamics reduces to statistical mechanics.[8] But why maintain that they go hand-in-hand? Consider what would obtain were this not the case. Suppose that, as a matter of sociological fact, physics was divided into different subfields than it actually is. Rather than addressing issues concerning relativity, quantum field theory, fluid dynamics and the like, the discipline was subdivided by the size of particle under investigation. One branch dealt with elements with an atomic mass under 10 *amu*, (studying the elements Hydrogen, Helium, Lithium, and Beryllium), another branch investigated the elements with atomic mass between 10-20 *amu* (studying the elements Boron, Carbon, Nitrogen, Oxygen, and Fluorine), etc.. If this were so, would it be the case that some branches of physics occupied

[6] Perhaps there could be an appeal to the notion of fundamentality. If one science is at a higher level than another, then facts regarding the latter are more fundamental than facts regarding the former. And if relative fundamentality itself forms a strict partial ordering over facts, it may be that an account of levels must form such an ordering over sciences. For an example of philosophers who subscribe to this criterion, see (Oppenheim and Putnam, 1958, pg. 7).

[7] Oppenheim and Putnam (1958) discusses the notion of reduction extensively in this context. They hold that there are three levels of the unity of science, two of which explicitly concern reduction. They state, for example, "Unity of Science in the weakest sense is attained to the extent to which all the terms of the science are reduced to the terms of some one discipline" (pg. 3), and later "Second, the Unity of Science in a stronger sense...is represented by the Unity of Laws. It is attained to the extent to which the laws of science become reduced to the laws of some one discipline" (pg. 4). Fodor (1974) mentions, but does not endorse the reductive conception of levels, saying "Saying that physics is basic science and saying that the theories in the special sciences must reduce to physical theories have seemed to be two ways of saying the same thing" (pg. 97). See, also, Nagel (1961).

[8] For discussions of this particular example—which remains among the most successful examples of reduction in the sciences, see Sklar (1993, 1999); Callender (1999); Albert (2000).

a higher level than the others? Arguably, no. The subdisciplines would fall into a strict partial ordering (for the simple reason that arranging particles by mass forms a strict partial ordering), so the first desideratum is satisfied. But there is no sense in which the disciplines could be said to reduce to one another. The relation between thermodynamics and statistical mechanics is unlike the relation between the study of Boron and the study of Beryllium precisely because Boron cannot be reduced to Beryllium.

Of course, reduction need not only occur between the levels of scientific disciplines—it may also occur within them. Nickles (1973) and Wimsatt (1976, 2006), for example, argue that there are two species of reduction: inter-level and intra-level. Inter-level reductions offer explanations of phenomena within a scientific discipline. It may, for example, explain how air pressure affects the distribution of clouds or how a complex chemical reaction reduces to a series of simpler ones. Intra-level reductions, in contrast, reduce phenomena at one scientific level to another. This is the ostensible reduction of macroeconomic phenomena to psychological phenomena, or of ecological phenomena to biological phenomena. Furthermore, there are various forms this desideratum might take depending upon the notion of reduction employed. Some advocate accounts of reduction in terms of causation/explanation (see Kim (1998)), organization (see Churchland and Sejnowski (1992)), size (see Kemeny and Oppenheim (1956); Oppenheim and Putnam (1958); Wimsatt (1976)), analysis (see Sheperd (1994)), or realization (see Gillett (2002)). For each notion of reduction, there is a corresponding conception of level: one according to which the higher levels reduce to the lower levels for that type of reduction.

The desideratum of reduction might also be described in terms of relevance; the lower level sciences are relevant to those that lie at higher levels than them. It does not suffice, when investigating interdisciplinary level, to demonstrate that two fields of study are compatible with one another. Chemistry and physics not only avoid conflict, but compliment—physical goings-on are relevant to chemical reactions. And it seems at least partially for this reason that chemistry plausibly lies at a higher level than physics. If two fields had nothing whatsoever to do with one another, this would preclude them from being relatively leveled. Accounts of scientific level ought to explain why this is the case: why it is that the respective disciplines are relevant to each other.

A related consideration concerns the possibility of *emergence.* Some maintain that objects bear emergent properties.[9] For example, it may be that minds depend upon brains, but that mental properties are, in some important respect, independent from the brain-states that they depend upon. Often, the possibility of emergence is taken to count against

[9] As with the interpretation of scientific level, there are numerous accounts of emergence in the literature. Some describe emergence in epistemic terms—see, e.g., Popper and Eccles (1977); Bedau (1997); Nagel (1961); Teller (1992). Roughly, the thought is that a higher-level property is emergent just in case its presence cannot be derived or understood from knowledge of lower-level properties. Others, however, describe emergence in metaphysical/ontological terms—see, e.g., O'Connor (1994); Humphreys (1996); Kim (1999). And, as with the characterization of scientific level, I restrict my attention to metaphysical interpretations of emergence for the purposes of this paper.

the claim that scientific disciplines are leveled.[10] If a discipline contains emergent properties, then it cannot be fully reduced to another discipline. However, others endorse accounts of level compatible with emergent properties.[11] The distinction between these approaches can also be understood in terms of relevance. For, if we require that leveled disciplines be *entirely* relevant to one another, the interpretation will preclude the presence of emergent properties, but if we only require that leveled disciplines be *at least partially* relevant to one another, emergence may abound.

There is, arguably, a deep conflict between the first and second desiderata. It might even be suggested that no account of level could possibly satisfy both and, consequently, that the very notion of level ought to be abandoned. Many maintain that reduction is closely tied to identity.[12] If one theory were to reduce to another, but facts about the former remained distinct from facts about the latter, it would seem to be reductive in name only. But if two disciplines are genuinely reductive, it is difficult to see how either could be at a higher level than the other. hat is to say, it appears that the claim that D_1 reduces to D_2 requires that $D_1 = D_2$. But if $D_1 = D_2$, then an application of Leibniz's Law ensures that every property D_1 bears is also borne by D_2. This, by stipulation, includes the property of *being at a higher level than* D_2, which entails that D_2 is at a higher level than itself. This violates irreflexivity, which I have already claimed to be indispensable to a theory of level. If an account were—somehow—able to satisfy both the first and second desiderata, it would count substantially in its favor.

3. To Allow For Properties To Be Multiply Realized

It is widely accepted that some properties can be *multiply realized*.[13] A property is said to be multiply realizable just in case it can be manifested by diverse underlying configurations. Plastic shaped in the appropriate way may form a cup, but cups can be made of metal or glass as well. And it may be that pain is associated with firing C-fibers in humans, but it is perfectly conceivable for organisms with diverse neurological profiles to experience phenomenal pain.

Some interpretations of scientific level are incompatible with multiply realizable properties.[14] For example, Nagel (1961) requires that the properties of the higher-level sciences be identified with properties in the lower-level sciences. In order for the biological property *being a heart* to reduce to a chemical property, there must be some chemical property that it is identical to. But if *being a heart* is multiply realizable (perhaps hearts can be com-

[10]For a discussion along these lines, see, e.g., Humphreys (2019).

[11]See, for example, Campbell (1974).

[12]For recent discussions along these lines, see Dorr (2016); Correia (2017).

[13]There is an extensive debate over how best to understand what multiple realizability consists of. To the extent that I can, this is a debate I wish to avoid. See, however, Heil (1999); Gillett (2003); Polger (2004); Morris (Forthcoming).

[14]See Fodor (1974) for the original discussion of this point. Wimsatt (2006) also maintains that an account of level ought to be compatible with multiple realizability.

posed of carbon, silicon, etc.) there may be no property which it is identical to. Of course, it is always possible to identify *being a heart* with the disjunction of its realizations—to claim that to be a heart is to either be carbon shaped thus and so, silicon shaped thus and so, etc.. But, some have argued, these disjunctive identifications are explanatorily poor. One learns much more about the nature of hearts by learning the function that hearts perform, rather than a lengthy disjunction. And because these disjunctive identifications are explanatorily inadequate, they are poor contenders for reduction.

Unlike the first two criteria, it is not entirely clear whether the multiple realizability objection is interpretive or descriptive. That is to say, there are two ways the objection might be put. It might be framed as a restriction on accounts of level—such that accounts which preclude properties from being multiply realizable are inadequate accounts—or, alternatively, it might be taken merely count against the presence of levels in the actual world. On the second approach, the presence of multiply realizable properties indicates that the disciplines do not stand at higher or lower levels from one another, but there is no need for an analysis of level to accommodate these types of properties. And so, some might maintain, an account of level need not allow for multiple realizability. Nevertheless, given the presumptive abundance of multiply realizable properties, it is plausible that permissive accounts are more likely to yield levels of scientific discipline.

4. To Remain Agnostic About What The Levels Of Science Are

It is desirable for accounts to remain neutral as to what the actual levels of science are. It may be that physics occupies a lower level than biology, and it may be that we have evidence to that effect, but this issue is not one which ought to be settled by considerations about level alone. What a level is the type of thing which can be demonstrated in a predominantly *a priori* manner; that is to say, the conditions in which one science stands at a higher level than another can be investigated without placing undue weight on the how the sciences are actually structured. But there are limits to the investigative power of armchair philosophy. Although one can investigate the notion of level through introspection, it is incumbent upon scientists to provide information about the way the world actually is. It may be, as Weinberg (1992) has claimed, that the arrows of explanation point to the very small; that the lowest level is comprised of a discipline like quantum field or string theory.[15] But, if this is so, it is a conclusion that requires empirical support. A theory of level which itself determines that quantum field theory (or some other discipline) occupies the lowest level

[15] Some metaphysicians have argued that the arrows of explanation point toward the very larger, rather than the very small—see, e.g., Schaffer (2010). I note, however, that this type of argument often appeals to empirical considerations. Schaffer maintains that the universe as a whole is in a state of quantum-entanglement, and that, consequently, there is more information regarding the whole than there is regarding its parts. Considerations about quantum entanglement are paradigmatic instances of empirical considerations.

oversteps its bounds.[16]

This is a criterion previous accounts have failed to achieve. One example occurs in 'The Unity of Science as a Working Hypothesis' (Oppenheim and Putnam (1958)). Oppenheim and Putnam outline a process of reduction that consists of three stages. In the first stage, the terms of the higher-order discipline are translated into terms of the lower level discipline; in the second, the laws of the higher-level discipline are reduced to laws of the lower-level discipline; and in the third, the laws of the lower-level discipline are themselves unified into one. Within the first level—in which the predicates of one discipline are translated into another, there is a process called 'micro-reduction.'[17] In this process, the parts of objects of the higher order science are the objects which satisfy the predicates of the lower-level science. For example, if chemistry were to be micro-reduced to physics, the predicate 'is water' is translated into the terms 'H_2O' only if the parts of the water molecule satisfy physical predicates.

An account of level in terms of micro-reduction places constraints on which sciences could be at higher levels than one another. It is impossible, on this approach, for a science which deals with large objects to be at a lower level than a science which deals with small objects. In order for the former object to occupy a lower level than the latter, the parts of the objects of latter must be micro-reduced into objects of the former—and how could it be that small objects are composed of large ones? It is thus possible to conclude that some disciplines are not at higher levels than others from the armchair—purely on the basis of an account of level and the size of objects involved. Notably, this failure occurs at the very first step of Oppenheim and Putnam's reduction: before any discussion about laws occurs. Differences in size thus prevent any type of reduction on their account. Such an account is not agnostic as to what the levels of science are, and so fails to satisfy the fourth desideratum.

5. To Permit Crossover In Subject-Matter Between Levels Of Discipline

The empirical sciences are a motley crew. There are no sharp dividing lines—such that the practitioners of one field dare not venture forth into another. Although 'Carbon Dioxide' may be a paradigmatic predicate of chemistry, ecologists investigate whether volcanic explosions release sufficient carbon dioxide to trigger mass extinctions; some psychologists study how risk-averse people typically are, while behavioral economists investigate how risk-aversion affects macroeconomic trends; and astronomers and physicists alike are concerned with the implications of general relativity. If the notion of levels of science was incompatible with interdisciplinary crossover, the prospects of scientific levels would be

[16] This point was hinted at in Fodor (1974), who claimed "I now want to suggest some reasons for believing that this consequence of reductivism is intolerable. These are not supposed to be knock-down reasons; they couldn't be, given that the question whether reductivism is too strong is finally an empirical question" (pg. 102).

[17] See, also, Kemeny and Oppenheim (1956).

poor.[18] Some have advocated abandoning the very notion of level on the grounds that no account could permit such interdisciplinary crossover.[19] Because it is impossible to identify the 'real level' of a phenomenon, the very notion of level may be suspect. However, if there were an account of level which allowed objects to occur at different levels, this type of objection would lose its bite.

Guttman (1976); Potochnik and McGill (2012) discuss this point at length. For them, the crossover of subject-matter isn't so much a problem for the notion of scientific level (they largely assume that levels disallow such crossover), but rather a reason to believe that levels of disciplines do not exist. One of Guttman's examples concerns the study of ecosystems. Although many traditionally conceive of ecosystems as composed of organisms, he notes that ecosystems are actually composed of numerous kinds of things. There are water and air molecules, rivers and mountains, etc.. Furthermore, the study of ecosystems does not concern itself solely with the organisms therein, but rather with how organisms interact with these other features of their environment.

This observation is in tension with any conception of level incompatible with interdisciplinary crossover (which, Shapiro (Forthcoming) argues, includes Oppenheim and Putnam (1958)'s view). If a concept of level requires that the levels be entirely isolated from one another, the prospects of levels in scientific discipline would be slim. Numerous things are objects of study in several disciplines. Craver (2007, 2015) argues on these grounds that the scientific disciplines, as actually practiced, do not correspond to levels within nature. Someone studying how ecological systems work would, by necessity, draw on resources from numerous levels in order to comprehend their object of study. So it may be that the current disciplines to not align themselves with whatever levels there are in nature. However, if there were a conception of scientific level which allowed for the crossover of subject-matter, it may assuage these types of concerns.

The criteria I have discussed are not exhaustive; there may well be further conditions which we could add. But they are enough to begin. I now turn to current developments in truth-maker semantics, which I rely upon in this account.

An Overview of the Truth-Maker Approach

The motivating thought behind truth-maker semantics is that there exists something within the world—a state of affairs, perhaps, or a way that the world is—which verifies, or renders true, something representational—such as a proposition or a sentence. Moreover, it is held that the meanings of the representational entities can be identified with that which makes

[18]This point is briefly endorsed by Oppenheim and Putnam (1958), when they allow for there to be crossover of language between scientific disciplines at different levels (pg. 5). However, they deny that an object at one level has parts at a higher level (pg. 9).

[19]See Wimsatt (2006).

them true.[20]

When stated so generally, this may seem uncontroversial. After all, a great many philosophers—tracing back at least to Tarski, and possibly as far back as Frege—have identified the meanings of sentences with their truth-conditions. What differentiates truth-maker semantics from more traditional approaches is its commitment to *exact* truth-makers. If a state of affairs verifies a proposition it does not merely necessitate its truth, nor is it merely partially relevant to its true, but rather it is *entirely* relevant to the its truth. So, while the state of affairs of grass being green and the sky being blue arguably verifies 'Grass is green and the sky is blue,' it does not verify '$2+2=4$' despite necessitating the sentence's truth, nor does it verify 'Grass is green' because a part of that state—the part concerning the sky being blue—is irrelevant to 'Grass is green.'

This approach takes seriously the claim that states of affairs are structured: that some states are proper parts of others. It may be that the state of roses being red is a proper part of the state of roses being red and violets being blue, and it may be that the state of Jane being a fox is a part of the state of Jane being a vixen. Given that states are capable of mereological composition, it is desirable to describe this structure within our formalism. This is accomplished with a state-space: an ordered pair $< S, \sqsubseteq >$ where S is a set of states of affairs, and $\sqsubseteq$ is a binary relation on S, with the intended interpretation of parthood, such that '$s \sqsubseteq s'$' asserts that state s is a part of state s'. Here, I make the standard assumption that parthood is a partial ordering—i.e., that $\sqsubseteq$ satisfies the following criteria:

REFLEXIVITY:	$s \sqsubseteq s$
ANTISYMMETRY:	$(s \sqsubseteq s' \wedge s' \sqsubseteq s) \rightarrow s = s'$
TRANSITIVITY:	$(s \sqsubseteq s' \wedge s' \sqsubseteq s'') \rightarrow s \sqsubseteq s''$

The only additional restriction is that state-spaces are *complete*—that is to say, they allow for arbitrary fusion. For states spaces of finite size, this can be accomplished simply by assuming that every two states within S have a fusion within S. However, this approach fails for infinitely large state-spaces. For these state-spaces, it may be that every finite collection of states within S has a fusion within S, but that there are infinitely large collections of states within S that lack a fusion within S.

Accommodating infinitely large state-spaces requires a few more definitions. First, we may let an *upper bound* of $T \subseteq S$ be a state which contains every state within T as a part: i.e., t is an upper bound of T iff $\forall s \in T, s \sqsubseteq t$. We then say that a state t is a *least-upper-bound* of $T \subseteq S$ iff it is an upper bound of T and is a part of all upper bounds of T: i.e., just in case if s is a least upper bound of T, then $t \sqsubseteq s$. Provably, if a set has a least upper bound, then it has a unique least upper bound.[21] We denote the least upper

[20] The development of truth-maker semantics is largely due to Fine (2013, 2016, 2017). I rely heavily on these developments within this paper.

[21] Suppose, for reductio, that a set T had two least upper bounds t and t'. Because they are both least upper bounds, they are both upper bounds. And because each least upper bound contains every upper

bound of T as $\bigsqcup T$. A complete state-space is one in which every subset of S contains a least upper bound within S. For the purposes of this paper, I restrict my attention to complete state-spaces.

The development of a semantics requires a language which meaning is attributed to. I restrict my attention to a simple, first-order language. This language contains infinitely many predicates $F_1, F_2, ...$, of fixed adicity, infinitely many names $a_1, a_2, ...$ such that there is a unique name for every object, and the logical operators $\neg, \wedge, \vee$—each of which is defined in the standard way. Additionally, this language is equipped with infinitely many variables $x_1, x_2, ...$ and the quantifiers $\exists, \forall$, which serve both to bind the variables and to express generality.

Let a model $\boldsymbol{M}$ be an ordered quadruple $< S, \sqsubseteq, I, |\cdot| >$ such that $< S, \sqsubseteq >$ is a complete state-space, I is the set of individuals, and $|\cdot|$ is a valuation function which takes, as its input, an atomic sentence (i.e., the application of a predicate to names of objects—something like 'John is human'), and has, as its output, an ordered pair $< V, F >$ where both V and F are subsets of S—intuitively those states of affairs which verify and falsify the input respectively. So, for example, if the valuation were to take 'Mary is tall' as its input, its output may be the ordered pair $< \{\textit{Mary being tall}\}, \{\textit{Mary being short}\} >$—i.e., the ordered pair whose first element is the singleton set containing the state of Mary being tall, and the second element is the singleton set containing the state of Mary being short. With the definition of a model in place, we may then define our semantics inductively:

$i.^+$ $s \Vdash Fa$ iff $s \in |Fa|^V$
$i.^-$ $s \dashv\!\mid Fa$ iff $s \in |Fa|^F$
$ii.^+$ $s \Vdash \neg A$ iff $s \dashv\!\mid A$
$ii.^-$ $s \dashv\!\mid \neg A$ iff $s \Vdash A$
$iii.^+$ $s \Vdash A \wedge B$ iff there exist t, u such that $t \Vdash A$ and $u \Vdash B$ and $s = t \sqcup u$.
$iii.^-$ $s \dashv\!\mid A \wedge B$ iff either $s \dashv\!\mid A$ or $s \dashv\!\mid B$
$iv.^+$ $s \Vdash A \vee B$ iff either $s \Vdash A$ or $s \Vdash B$
$iv.^-$ $s \dashv\!\mid A \vee B$ iff there exist t, y such that $t \dashv\!\mid A$ and $u \Vdash B$ and $s = t \sqcup u$

It is my hope that this semantics is extraordinarily intuitive. Negation swaps a sentence's verifiers for its falsifiers; if the state of it being windy verifies 'It is windy' then it falsifies 'It is not windy.' Verifiers of conjunctions are fusions of verifiers of their conjuncts; if the state of the ball being red verifies 'The ball is red,' and if the state of the ball being round verifies 'The ball is round,' then the fusion of these states—the state of the ball being red and being round—verifies 'The ball is red and round.' Verifiers of disjunctions are verifiers of a disjunct; if the state of water being wet verifies 'Water is wet,' then it also verifies 'Water is wet or sand is wet.'

There are several ways to expand this semantics to clauses with quantifiers. We might,

bound as a part, it follows that $t \sqsubseteq t'$ and $t' \sqsubseteq t$. Given antisymmetry, this then entails $t = t'$.

for example, countenance generic objects—so that a verifier of 'Everything is F' is a verifier of a generic object being F. Here, the approach I adopt instead is instantial. Verifiers of universal statements are fusions of verifiers of their instances. So a verifier of '$\forall xFx$' is the fusion of a verifier of 'Fa' with a verifier of 'Fb,' etc.. Verifiers of existential statements are verifiers of their witnessing instances. The state of affairs which verifies '$\exists xFx$' is a state of affairs which makes it the case that a particular object is F. More formally, we have:

$v.^+$ $s \Vdash \forall xFx$ iff there is a function $f : I \to S$ such that $f(i) \Vdash F(i)$ for all $i \in I$ and $s = \bigsqcup\{f(i) : i \in I\}$

$v.^-$ $s \dashV \forall xFx$ iff there is some a such that $s \dashV Fa$

$vi.^+$ $s \Vdash \exists xFx$ iff there is some a such that $s \Vdash Fa$

$vi.^-$ $s \dashV \exists xFx$ iff there is a function $f : I \to S$ such that $f(i) \dashV F(i)$ for all $i \in I$ and $s = \bigsqcup\{f(i) : i \in I\}$

There is a wide variety of philosophical uses for this semantics. Some have argued that it underlies the logic of analytic content (see Fine (2013, 2016)), deontic logic (see Fine (2018*a*,*b*)), counterfactual conditionals (see Fine (2012*a*)) and philosophical analysis (see Correia and Skiles (2017); Elgin (Forthcoming)). But its closest application, to our present concern, occurs in Elgin (2020). There, I present, and to some extent defend, an interpretation of identity theory in terms of truth-maker semantics. In particular, I claim that the distinction between type-identity theory (the claim that every type is identical to a physical type) and token-identity theory (the claim that every token is identical to a physical token) is dissolved, and that this dissolution resolves canonical problems with both interpretations.

At the time, I believed that approach to be incongruous with a leveled conception of scientific disciplines. By advancing an interpretation according to which everything is identical to the physical, I promoted a view which seemed to be at best unsuitable for, and at worst incompatible with, levels of science. However, it has since occurred to me that the truth-maker approach may also be employed to develop an account of level. It is my hope that these dual applications vindicate one another: the fact that the very same semantics possesses the resources for an account of identity and an account of level lends support to both interpretative aims.

An Account of the Levels of Science

I seek conditions for one scientific discipline to lie at a higher level than another: for what it is that completes the biconditional *Higher Level* (D_1, D_2) *iff ...*, where both D_1 and D_2 are disciplines of science. In order to approach this topic systematically, it is incumbent to begin by accounting for what D_1 and D_2 are: to describe what it is that a scientific discipline consists of.

Here, I identify disciplines with sets of predicates.[22] We might, for example, identify chemistry with {*'is a chemical compound', 'is carbon', ...* }. Of course, there is a great deal more to a scientific discipline than a set of predicates. Each may come with its own laws, methodologies, questions, journals, and much more besides. The identification of disciplines with predicates might seem to be a gross oversimplification—perhaps so much so that it threatens the viability of this program from the outset. No matter. It may be that my project is only one step toward a more complete story, but it remains an important step to take.

But it is not enough to claim that each discipline is identified with a set of predicates, for that does not determine which predicates are associated with which disciplines. What is it in virtue of that 'is extinct' is not plausibly a predicate of chemistry, and that 'is spin-up' is identified with quantum-mechanics, rather than ecology?

There are at least two approaches we might take. The first is constructivist in spirit. Perhaps the predicates of a science are simply the predicates that practitioners of that science actually use. If we want to discover which predicates are physical predicates, we must simply look at the physics journals; if practicing physicists discuss 'mass' then 'mass' is a physical predicate, and if ecologists use ' is symbiotic' then 'is symbiotic' is an ecological predicate. On this conception, scientists play an integral role in what the science consists of. For, in their choice of predicates, they determine which predicates are assigned to which discipline.

Another approach calls for less reliance upon scientific practice. Rather than taking usage to determine the predicates of a scientific domain, we might, rather, identify the predicates of a discipline with those that figure in a statement of its laws.[23] Thus, for example, if $F = ma$ were a law of physics, then 'force,' 'mass,' and 'acceleration' would all belong to the language of physics. And if the special sciences are also equipped with their own laws (perhaps Gresham's Law is a law of economics, the Ideal Gas Law is a law of chemistry, etc.) they too can be identified with predicates occurring within these laws. Of course, there may be important differences between the laws of physics and the laws of the

[22] For a precursor to this identification, see Oppenheim and Putnam (1958), who assert "We shall suppose that with each level there is associated a list of the theoretical predicates normally employed to characterize things on that level at present...And when we speak of a theory concerning a given level, we will mean not only a theory whose universe of discourse is that level, but one whose predicates long to the appropriate list" (pg. 10).

[23] This method was suggested by Fodor (1974), who claimed "Every science implies a taxonomy of the events in its universe of discourse. In particular, every science employs a descriptive vocabulary of theoretical and observational predicates such that events fall under the laws of that science by virtue of satisfying those predicates...If I knew what a law is, and if I believed that scientific theories consist just of bodies of laws, then I could say that P is a natural kind predicate relative to S iff S contains proper laws of the form $Px \rightarrow \alpha x$ or $\alpha x \rightarrow Px$; roughly, the natural kind predicates of a science are the ones whose terms are the bound variables in its proper laws" (pg. 101-2). For the purposes of this paper, I will largely sidestep the further question of what it takes for something to be a law of science. I take it that the identification of scientific disciplines with predicates figuring in statements of law is available to both the Humean and anti-Humean.

special sciences—it is widely believed that while the laws of physics hold universally, the laws of the special sciences allow for exceptions. And it is worth noting that any scientific discipline that did not involve laws of some kind or other could not appeal to this method of identification. But, insofar as many diverse disciplines employ laws, these laws could be used to select a set of predicates. This method might be seen to reverse the order of Oppenheim and Putnam's conception of reduction. Rather than first reducing the language of one discipline to another before reducing the laws, this approach employs the laws in order to determine what it is the relevant languages are.

However it is that predicates are ultimately determined, select two disciplines which are identified by the following:

$D_1 = \{F_1, F_2, ...\}$
$D_2 = \{G_1, G_2, ...\}$

Where the number of predicates within each discipline may or may not be finite.

The motivation behind this account is that the relation between D_1 and D_2 arises from the mereological structure of states of affairs. It may be that 'a is a water molecule' has verifiers, and that these verifiers have proper parts.[24] Perhaps the state which verifies that a is water is itself composed of states of affairs concerning hydrogen and oxygen—i.e., perhaps that which makes it the case that a is a water molecule is something which can be decomposed into states which make it the case that the parts of a are hydrogen and oxygen composed in a particular configuration. If this is correct, we might account for the difference in level between chemistry and physics, for example, by appealing to the fact that the verifiers of chemical statements (i.e., statements which predicate a chemical predicate of an object or some objects) are composed of verifiers of physical statements (i.e., statements which predicate a physical predicate of an object or some objects). So, at an extremely rough first pass, we might claim:

Higher Level(D_1, D_2) iff
$s \Vdash Fa \rightarrow (((t) \sqsubseteq s) \rightarrow (t) \Vdash Ga)$

For the moment, let (t) remain a free variable ranging over states of affairs. This proposal claims that discipline D_1 is at a higher level than discipline D_2 just in case, if state s verifies Fa, then if (t) is a part of s, then t verifies Ga. Obviously, refinements are required at the outset—minimally, s, F, a and G must be replaced by terms bound by various quantifiers. After all, it is not enough for there to be a particular state of affairs, predicate and object for which this condition holds; rather, it applies generally. Interestingly, the choice and placement of these quantifiers impacts the satisfaction of

[24]Note that this particular example is more amenable to the first, rather than the second, method of identifying the predicates of scientific disciplines. It seems unlikely that there are laws which mention water.

the theoretical desiderata.[25] Replacing the terms with variables under the appropriate quantifiers results in the following:

Higher Level(D_1, D_2) iff
$\forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow ((t) \sqsubseteq s \rightarrow \exists G_m((t) \Vdash G_m x)))$

As before, (t) remains a free variable. This claims that D_1 is at a higher level than D_2 just in case for all states of affairs, for all predicates within D_1, and for all objects, if a state verifies that an object falls under the scope of a higher-level predicate, then if (t) is a part of that state, then (t) verifies that the object falls under the scope of a lower-level predicate.

Yet another refinement is in order. It need not be the very same object which satisfies the higher-level predicate be the object which satisfies the lower-level predicate. If an object is a water molecule, it need not be the very same object which satisfies the predicates 'hydrogen' and 'oxygen.' So instead of requiring that a state which verifies that an object is F is composed of states which verify that *the very same object* is G, I allow for these states to verify that some object or other is G, i.e.:

Higher Level(D_1, D_2) iff
$\forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow ((t) \sqsubseteq s \rightarrow \exists G_m \exists y((t) \Vdash G_m y)))$

Perhaps some suspect that further restrictions are needed After all, if an object is a water molecule, it is not merely the case that some-objects-or-other are hydrogen and oxygen; rather, the parts of that very water molecule are hydrogen and oxygen. So, perhaps we ought to impose the further requirement that the objects which satisfy the predicates of the lower-level discipline compose the objects which satisfy the predicate of the higher-level discipline.

This is not an approach I take. I note that as the formalism stands, the relation of mereological composition is not defined upon the set of objects; it is a relation that holds between states of affairs. In order to describe mereological relations between objects, the semantics would need to be revamped—to reintroduce a notion of composition which holds between objects. Of course, nothing would stop us from modifying the semantics in this way, but it is incapable of this further refinement as it is currently formalized.

So far so good, but we now face the elephant in the room: the free variable (t). As I suspect everyone with even a rudimentary understanding of logic has thought of by now, an obvious thing to do is to bind this variable with a universal quantifier. On this proposal, if a state verifies that an object is F (for some higher-level predicate F), it must be the case that every part of that state verifies that an object is G (for some lower-level predicate G). We would then have:

[25] This point is discussed in greater depth when below in reference to the desideratum concerning multiple realizability.

Higher Level(D_1, D_2) iff
$\forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow \forall t(t \sqsubseteq s \rightarrow \exists G_m \exists y(t \Vdash G_m y)))$

This proposal has the advantage of being truth-evaluable: it has the disadvantage of being false. The problem is perhaps easiest to appreciate by shifting back to the (arguably more conventional) way of understanding mereology as a relation between objects. If a water molecule is composed of hydrogen and oxygen, it isn't the case that every part of that water molecule is either hydrogen or oxygen. After all, these atomic parts can themselves be decomposed into their subatomic constituents. A proton which partially composes the oxygen atom is itself a part of the water molecule, but the proton is neither hydrogen nor oxygen. This problem resurfaces when mereology is taken to be a relation between states. Suppose that state s is the state of a's being a water molecule, and further that this state verifies 'a is a water molecule.' It may be that this state can be decomposed into states concerning atomic physics—i.e., states concerning hydrogen and oxygen. These states may themselves be decomposed into states which verify that objects are electrons, protons, quarks, and the like. If this is so, then state s has parts which do not verify that an object satisfies the predicates of atomic physics. Some of its parts concern *subatomic* physics, rather than atomic physics. And so, on the present proposal, this would insure that chemistry is not at a higher level than atomic physics. But, surely, this is not the kind of thing which ought to prevent one discipline from occupying a higher level than another. So the universal quantifier doesn't work: it's just too strong.

Exchanging the universal for an existential quantifier is hardly an improvement. If all that we require of a higher-level science is that a part of a verifier for one of its expressions involves a lower-level science, there seems no hope for a notion of reduction. Suppose, for example, that there were a discipline which involved the interactions of atomic physics and disembodied minds. A state verifies 'Fa' in this discipline, just in case a part of it verifies that there is a disembodied mind and another part verifies that a is a hydrogen atom. In this case, a part of a verifier of 'Fa' concerns atomic physics, so this discipline would occupy a higher level than atomic physics (assuming that other verifiers acted appropriately as well). But it would be absurd to take this to lend support to the claim that this discipline reduces to atomic physics. After all, a part of its subject-matter is disembodied minds; something which has nothing to do with atomic physics at all.The universal quantifier is far too strong, the existential quantifier is far too weak. Some intermediate position is required instead.[26]

For the sake of clarity, let us once again revert to discussions of mereology in terms of objects. What does it mean to claim that two hydrogen and one oxygen atoms compose a

[26]It might also be suggested that we require a notion of normality or typicality: perhaps a typical part of a verifier of the higher-level discipline involves a verifier of the lower level discipline. I myself am skeptical that this strategy will succeed. It seems eminently plausible to me that a a verifier of 'a is a hydrogen atom' involves subatomic, rather than atomic particles—after all, every helium atom is composed of subatomic particles.

water molecule. It isn't to claim that the only parts of the water molecule are the hydrogen and oxygen atoms; after all, the parts of these atoms are themselves parts of the molecule. Rather, the claim is that the hydrogen and oxygen atoms collectively leave nothing out—the object which is composed of the hydrogen and oxygen atoms misses no part of the water molecule; it is identical to it. A similar move can be made with regard to the mereology of states of affairs. The claim that the parts of state s verify that something is G does not amount to the claim that *all* parts of s verify that something is G. Rather, it is the claim that we can fully describe state s—we can leave nothing out—when describing its parts that verify that something is G. That is to say, the fusions of the parts of s (each of which verify that something is G) have a fusion which is identical to s.

There are (at least) two ways could represent this formally, one of which employs plural quantification and the other of which quantifies over sets. I will primarily address the formulation in terms of set-quantification, but I mean nothing metaphysically robust by that choice. As before, allowing S to be the set of states of affairs, results in the following condition:

> *Higher Level*(D_1, D_2) iff
> $\forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow \exists T \subseteq S(\bigsqcup T = s \wedge \forall t \in T, \exists G_m, \exists y(t \Vdash G_m y)))$

The notation is becoming more cumbersome, but the underlying thought (hopefully) remains intuitive. If a state of affairs verifies that an object is F (where F is a predicate of the higher-level discipline), then there exists some set of state of affairs, the fusion of which is identical to s, and such that each element of that set verifies that an object is G (where G is a predicate of the lower-level discipline). This is perfectly compatible with with the claim that s has parts which don't verify that something is G; all that is required is that s is identical to some fusion or other of states which *do* verify that something is G. If these states themselves have parts which are unrelated to G, that's perfectly fine. We also resolve the problem which plagued the existential quantifier—of a discipline concerning atomic physics and disembodied minds. If a state s cannot be decomposed into states which purely concern atomic physics (because, perhaps, one part of s concerns disembodied minds), then it does not satisfy the present conditions.

At long last, we have arrived at a putative account of what it takes for a discipline to be at a higher level than another. It is now possible to examine how it fairs—to determine whether it satisfies the desiderata for a theory of level. The first, and arguably most indispensable, criterion was that an account ought to form a strict-partial ordering over the disciplines—that it ought to be irreflexive, transitive and asymmetric. So how does the present account fare?

Not well, unfortunately. The relation is transitive, alright, but it's also reflexive. That is to say, not only is this account *compatible* with the claim that a discipline is at a higher than itself, but rather it *entails* that every discipline is at a higher level than itself.[27]

[27] To see why this is the case, select an arbitrary discipline D, which may be identified with the predicates

Something has gone wrong, and rather catastrophically so. In comparison to accounts with a free variable, this at least has the virtue of being truth-evaluable—but it has the vice of being false. It cannot be correct as it stands, for it fails to satisfy a central requirement for a theory of level.

What is it that went wrong? It seems to me that the account has narrowly missed its mark. The relation it defines is not that of *being at a higher level than*, but rather *being at the same or a higher level than.* I had attempted to define $>$, but ultimately defined $\geqslant$ instead. But once we have a definition of $\geqslant$, it is straightforward to define $>$. To be greater than is to be greater than or equal to and not equal to. In the present context:

> *Higher Level(D_1, D_2)* iff
> $\forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow \exists T \subseteq S(\bigsqcup T = s \wedge \forall t \in T, \exists G_m, \exists y(t \Vdash G_m y))) \wedge D_1 \neq D_2$.

This simply results from appending the requirement that the disciplines not be identical to the previous account. What does it mean to claim that $D_1 \neq D_2$? On the present approach, disciplines are identified with sets of predicates, so to say that two disciplines are distinct is to say that their respective predicates are distinct.

There are two ways in which this requirement might be met—one more demanding than the other. On the more demanding conception, we might require that the discipline's predicates be *entirely* distinct—that no predicate employed within one discipline be employed by the other. On the less demanding conception, all that is required is that the disciplines have *at least some* predicates that are distinct. Perhaps they have no predicates in common at all, but there may be some overlap. All that is required is that one discipline have a predicate which is not a predicate of the other.

I suspect that the demanding conception is too restrictive for practical purposes. Of course, from a logical perspective, the conditions are perfectly well defined. But I think it unlikely that any scientific discipline is at a higher level than another with this restriction in place. Minimally, it seems inevitable that numerous disciplines will employ mathematical predicates. If this practice precluded them from being at higher levels than the other, it seems unlikely that the disciplines would be leveled. However, even if we jettison the restrictive conception, the moderate one remains. All that is required, on this conception, is that a discipline have some predicates that the other lacks. But whichever approach we adopt, the first theoretical desideratum is satisfied: this account forms a strict partial ordering.

The second requirement was that an account of level ought to explain the sense in which higher level sciences reduce to lower level sciences. If chemistry is at a higher level than physics, there ought to be a way in which chemical truths can be reduced to physical truths.

$F_1, F_2, \ldots$. Select an arbitrary s, F_n and x such that $s \Vdash F_n x$—i.e., an arbitrary state of affairs that an arbitrary object is F for an arbitrary F. In this case, there is a $T \subseteq S$ (in particular, $\{s\}$) such that $\bigsqcup T = s$ (i.e., $\bigsqcup\{s\} = s$) and every element of T verifies that some object or other is F_n (i.e., $\exists x(s \Vdash F_n x)$).

This is a requirement the present account easily accommodates. If chemistry occupies a higher level than physics, then states of affairs which verify that an object is F (for a chemical predicate F) are composed of states of affairs which verify that an object is G (for a physical predicate G). The reason this account is reductive is precisely the same reason that other mereological accounts are reductive: the fusion of parts is literally identical to a whole.

The third criterion is that an account of scientific level ought to allow for predicates to be multiply realized. It may be that 'heart' is a biological predicate, but that hearts may be composed of many types of things. Perhaps carbon shaped thus-and-so constitutes a heart in many cases, but an artificial heart composed of plastic counts as well. Minimally, an account of level ought not preclude the possibility that some predicates may be multiply realized.

It is here that the power of the truth-maker account comes to the fore. There is no requirement, on this approach, that the truth-makers of predicates resemble one another in any way. The claim 'John has a heart' may have a truth-maker which is vastly dissimilar from truth-makers of 'Jane has a heart.' For a higher-level predicate F, all that is required is that, for an arbitrary name a, Fa be decomposable into states concerning lower level predicates G. There is no requirement that these be the same lower level predicates which Fb is decomposible into. It may be that a verifier of Fa concerns predicates $G_1 - G_m$, whille a verifier of Fb concerns predicates $G_n - G_o$. That is to say, what makes it the case that a is F concerns some lower-level predicates, and what makes it the case that b is F concerns different lower-level predicates. So long as each instance may be decomposed into states concerning some lower-level predicates or other, the present conditions are satisfied.

It was important, when developing this account, to place the quantifiers as they are placed. Consider the following alternative, which simply shifts the placement of an existential quantifier:

Higher Level(D_1, D_2) iff
$\forall s, \forall F_n, \forall x, \exists G_m(s \Vdash F_n x \rightarrow \exists T \subseteq S(\bigsqcup T = s \wedge \forall t \in T, \exists y(t \Vdash G_m y))) \wedge D_1 \neq D_2$.

This account is less equipped to accommodate multiple realizability. It requires that, for every predicate of the higher-level science, there be a unique lower-level predicate such that states which verify the higher level predicate may be decomposed into states concerning the lower level predicate. If a state which verifies 'John has a heart' may be decomposed into states concerning 'Carbon,' then 'Jane has a heart' must be decomposable into states concerning 'Carbon' as well (assuming that biology is at a higher level than chemistry).

Moving the quantifier further left results in an account which is more restrictive still:

Higher Level(D_1, D_2) iff
$\exists G_m, \forall s, \forall F_n, \forall x(s \Vdash F_n x \rightarrow \exists T \subseteq S(\bigsqcup T = s \wedge \forall t \in T, \exists y(t \Vdash G_m y))) \wedge D_1 \neq D_2$.

This does not only require that states concerning higher-level predicates be decomposable into states concerning (the same) lower-level predicate. Rather, it makes the stronger claim that there is a unique lower-level predicate which every higher-level predicate may be decomposed into. Both of these alternatives are far more restrictive than the original account which, in contrast, has no difficulty in accounting for predicates which are multiply realized.

The fourth requirement was that an account ought not to take a stand on what the levels of the empirical sciences actually are. One cannot, simply by reflecting upon the concept of level, come to realize that ecology is at a higher level than physics. And we recall that this is a criterion that other accounts failed to achieve. Some, like Oppenheim and Putnam (1958), took a stand in requiring that higher-level sciences address larger objects than lower-level sciences did.

This is an area where the shift to discussions of mereology in terms of states of affairs, rather than objects, proves beneficial. It is natural to think of the mereology of states as mirroring, perhaps imperfectly, the mereology of objects. So if hydrogen and oxygen compose water, states of affairs concerning hydrogen and oxygen compose states of affairs concerning water. And, indeed, many examples I have used throughout this paper take that precise form. However there is nothing in the truth-maker approach which requires this alignment. It may be that the mereology of states of affairs comes entirely apart from the mereology of objects. Perhaps oxygen and hydrogen compose water, but states of affairs about water compose states of affairs about oxygen and hydrogen. This may be unintuitive, but there is nothing from a semantic perspective which precludes this possibility. And so this account does *not* assume that sciences concerning smaller objects are the only candidates for lower-level sciences. Of course, it may turn out that these types of objects lie at the more fundamental level, but this is not something which follows from the account of level alone.

The last criterion is that I mentioned is that there should be some crossover between the subject matter of disciplines at different levels. Coming to recognize that two fields are compatible may increase our general understanding, but compatibility is not itself enough to guarantee that the sciences operate at different levels from one another.

In the first place, this is achieved by allowing the same predicates to occur within disciplines at different levels. If both ecology and chemistry employ the predicate 'hydrogen,' then they may be disciplines which concern hydrogen. And the more predicates that disciplines have in common, the greater the overlap in their subject matter will be.

As it turns out, there already exists an account of subject-matter in terms of truth-maker semantics. **?** outlines one such account, partially in response to Yablo (2014). Fine is primarily concerned with the subject-matter of sentences, rather than disciplines. He identifies the subject-matter of sentences with the fusions of their verifiers. Let us suppose that 'Roses are red or violets are blue' has two verifiers—the state of roses being red and the state of violets being blue. In this case, the subject-matter of the sentence—what the sentence is about—is the state of affairs of roses being red and violets being blue. Any other sentence whose fusion of verifiers is the same (e.g., the sentence 'Roses are red and violets are blue') is about precisely the same thing. Some sentences have a subject matter which is a part of others. If the only verifier of 'Roses are red' is the state of roses being red, then the subject-matter of 'roses are red' is a part of the subject matter of 'Roses are red or violets are blue.' The subject-matter of the atomic sentence is a literal part of the subject-matter of the disjunctive sentence.

It is readily possible to expand this account of subject-matter to disciplines. Once we identify disciplines with sets of predicates, we might identify the subject matter of a discipline with the fusion of the verifiers of all sentences within that language. So, for example, if chemistry consists partially in 'Nitrogen' and 'Helium,' then the subject-matter of chemistry will be the fusion of states of affairs which verify that a is hydrogen with those that verify that b is Helium, etc..

The contention that leveled disciplines are about the same thing can be interpreted almost literally on the present approach. The states of affairs which make it the case that higher-level predicates obtain are all composed of states which make lower-level predicates obtain. So the subject matter of a higher level discipline is literally a part of the subject-matter of the lower-level discipline. And so this accounts for leveled disciplines to share the same subject-matter.

Conclusion

It has been my aim to explicate an account of scientific level on the truth-maker approach. This account, I maintain, satisfies numerous plausible criteria for scientific level. As such, it is a promising interpretation.

I close by noting the relation between this account and other aspects of my work. In Elgin (2020), I argued that truth-maker semantics possesses the resources for an account of identity theory: a plausible interpretation of the claim that everything is identical to the physical. As an identity relation, this interpretation was reflexive, transitive and symmetric. I have here argued that the very same semantics possesses the theoretical resources for an interpretation of level; a transitive, irreflexive and asymmetric relation. That the same framework accommodates two ends (incommensurable as they may seem) offers some vindication for the approach as a whole.

Independently, in Elgin (Forthcoming), I argue that truth-maker semantics is the appropriate setting for generalized identity: sentences of the form 'To be F is to be G' (e.g., 'To be morally right is to maximize utility,' 'To be a person is to be a rational animal.) which share the logical and modal profile of identity. These sentences themselves are reflexive, transitive and symmetric. However, there is another reading of 'To be F is to be G' which does not resemble an identity. On this reading, sentences of the form 'to be F is to be F' are universally false, and if 'To be F is to be G' is true, then 'To be G is to be F' is false. This alternate reading might, instead of a 'generalized identity,' be referred to as a ‘real definition.’ And so, as with interpretations of scientific discipline, there is one reading which resembles and identity, and another which is ordered.

It is my view that the two problems are not only analogous, but identical. Any resources which provides an adequate account of science will provide an account of metaphysics as well. Thus far, I have employed truth-maker semantics to provide an account of generalized identity, identity-based interpretations of physicalism, and the levels of scientific discipline. It remains to be shown how this approach may account for real definition as well.

References

Albert, David. 2000. *Time and Chance*. Harvard University Press.

Bedau, Mark. 1997. Weak Emergence. In *Philosophical Perspectives, 11: Mind, Causation and World*. Blackwell pp. 375–99.

Callender, Craig. 1999. "Reducing Thermodynamics to Statistical Mechanics: The Case of Entropy." *The Journal of Philosophy* 96(7):348–373.

Campbell, Donald. 1974. Downward Causation in Hierarchically Organized Biological Systems. In *Studies in the Philosophy of Biology*, ed. Francisco Jose Ayala and Theodosius Dobzhansky.

Churchland, Patricia and Terrence Sejnowski. 1992. *The Computational Brain*. MIT Press.

Correia, Fabrice. 2017. "Real Definitions." *Philosophical Issues* 27(1):52–73.

Correia, Fabrice and Alexander Skiles. 2017. "Grounding, Essence and Identity." *Philosophy and Phenomenological Research* 98(3):642–70.

Crane, Tim and D. H. Mellor. 1990. "There is no Question of Physicalism." *Mind* 99(394):185–206.

Craver, Carl. 2007. *Explaining the Brain: Mechanisms and the Mosaic Unity of Neuroscience*. Oxford University Press.

Craver, Carl. 2015. Levels. In *Open MIND*, ed. T. Metzinger and J. Windt. pp. 1–26.

Dasgupta, Shamik. 2014. "The Possibility of Physicalism." *The Journal of Philosophy* 111(9-10).

Della Rocca, Michael. 2014. "Razing Structures to the Ground." *Analytic Philosophy* 55(3):276–94.

deRosset, Louis. 2017. "Grounding the Unreal." *Philosophy and Phenomenological Research* 95(3):1–29.

Dorr, Cian. 2016. "To be F is to be G." *Philosophical Perspectives* 1:39–134.

Elgin, Samuel. 2020. "Physicalism and the Identity of Identity Theories." *Erkenntnis* pp. 1–20.

Elgin, Samuel. Forthcoming. "The Semantic Foundations of Philosophical Analysis.".

Fine, Kit. 2012*a*. "Counterfactuals Without Possible Worlds." *The Journal of Philosophy* 109(3):221–46.

Fine, Kit. 2012*b*. A Guide to Ground. In *Metaphysical Grounding: Understanding the Structure of Reality*, ed. Fabrice Correia and Benjamin Schieder. Cambridge University Press pp. 37–80.

Fine, Kit. 2012*c*. "The Pure Logic of Ground." *The Review of Symbolic Logic* 5(1):1–25.

Fine, Kit. 2013. "A Note on Partial Content." *Analysis* 73(3):413–9.

Fine, Kit. 2016. "Angellic Content." *Journal of Philosophical Logic* 45(2):199–226.

Fine, Kit. 2017. Truthmaker Semantics. In *A Companion to the Philosophy of Language, Second Edition*, ed. Bob Hale, Crispin Wright and Alexander Miller. Blackwell pp. 556–77.

Fine, Kit. 2018*a*. "Compliance and Command I: Categorical Imperatives." *Review of Symbolic Logic* 11(4):609–33.

Fine, Kit. 2018*b*. "Compliance and Command II: Imperatives and Deontics." *Review of Symbolic Logic* 11(4):634–64.

Fodor, J. A. 1974. "Special Sciences (Or: The Disunity of Science as a Working Hypothesis)." *Synthese* 28(2):97–115.

Gillett, Carl. 2002. "Dimensions of Realization: A Critique of the Standard View." *Analysis* 62(276):316–23.

Gillett, Carl. 2003. "The Metaphysics of Realization, Multiple Realization and the Special Sciences." *The Journal of Philosophy* 100:591–603.

Guttman, Burton. 1976. "Is 'Levels of Organization' a Useful Concept?" *Bioscience* 26(2):112–3.

Heil, John. 1999. "Multiple Realizability." *American Philosophical Quarterly* 36(3):189–208.

Humphreys, Paul. 1996. "Aspects of Emergence." *Philosophical Topics* 24(1):52–70.

Humphreys, Paul. 2019. *Philosophical Papers*. Oxford University Press.

Kemeny, John and Paul Oppenheim. 1956. "On Reduction." *Philosophical Studies* 7(1-2):6–19.

Kim, Jaegwon. 1998. *Mind in a Physical World*. MIT Press.

Kim, Jaegwon. 1999. "Making Sense of Emergence." *Philosophical Studies* 95:3–36.

Morris, Kevin. Forthcoming. “Multiple Realization and Compositional Variation.” *Synthese* pp. 1–19.

Nagel, Ernest. 1961. *The Structure of Science*. Harcout Brace.

Nickles, Thomas. 1973. “Two Concepts of Inter-Theoretic Reduction.” *Journal of Philosophy* 70:181–201.

O’Connor, Timothy. 1994. “Emergent Properties.” *American Philosophical Quarterly* 31:91–104.

Oppenheim, Paul and Hilary Putnam. 1958. “Unity of Science as a Working Hypothesis.” *Minnesota Studies in the Philosophy of Science* 2:3–36.

Polger, Tom. 2004. *Natural Minds*. MIT Press.

Popper, Karl and John Eccles. 1977. *The Self and its Brain*. Springer International.

Potochnik, Angela and Brian McGill. 2012. “The Limitations of Hierarchal Organization.” *Philosophy of Science* 79:120–40.

Schaffer, Jonathan. 2009. On What Grounds What. In *Metametaphysics: New Essays on the Foundations of Ontology*, ed. David Chalmers, David Manley and Ryan Wasserman. Oxford University Press pp. 347–83.

Schaffer, Jonathan. 2010. “Monism: The Priority of the Whole.” *The Philosophical Review* 119:31–76.

Schaffer, Jonathan. 2017. “The Ground Between the Gaps.” *Philosopher’s Imprint* 17(11):1–26.

Shapiro, Lawrence. Forthcoming. “Rethinking the Unity of ZScience Hypothesis: Levels, Mechanisms and Realization.”.

Sheperd, Gordon. 1994. *Neurobiology*. Oxford University Press.

Sklar, Lawrence. 1993. *Physics and Chance: Philosophical Issues in the Foundations of Statistical Mechanics*. Cambridge University Press.

Sklar, Lawrence. 1999. “The Reduction(?) of Thermodynamics to Statistical Mechanics.” *Philosophical Studies* 95:186–202.

Teller, Paul. 1992. A Contemporary Look at Emergence. In *Emergence or Reduction? Essays on Prospects of Nonreductive Physicalism*, ed. Ansgar Beckermann, Hans Flohr and Jaegwon Kim. De Gruyter pp. 139–54.

Wang, Zhi-Yong, Cai-Dong Xiong and Bing He. 2008. "Superliminal Propagation of Evanescent Modes as a Quantum Effect." *Annalen der Physik* 17(5):319–25.

Weinberg, Steven. 1992. *Dreams of a Final Theory.* Random House.

Wilson, Jessica. 2014. "No Work for a Theory of Grounding." *Inquiry* 57(5-6).

Wimsatt, William. 1976. Reductive Explanation: A Functional Account. In *PSA-1974 (Boston Studies in the Philosophy of Science, vol. 30*, ed. A. C. Michalos, C. A. Hooker, G. Pearce and R. S. Cohen. Reidel pp. 671–710.

Wimsatt, William. 2006. "Reductionism and its Heuristics: Making Methodological Reductionism Honest." *Synthese* 151(3):445–75.

Yablo, Steven. 2014. *Aboutness.* Princeton University Press.