Foregrounding and Backgrounding: A New Interpretation of “Levels” in Science

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**Forthcoming in *The European Journal for Philosophy of Science****.*

**Abstract:** Talk of “levels” can be found throughout the sciences, from “levels of abstraction”, to “levels of organization”, to “levels of analysis” (among others). This has led to substantial disagreement regarding the ontology of levels, and whether the various senses of levels each have genuine value and utility to scientific practice. In this paper, I propose a unified framework for thinking about levels in science which ties together the various ways in which levels are invoked in science, and which can overcome the problems that different senses of levels have faced. I argue that levels can best be understood as choices scientists make regarding what sort of information to foreground in their models and theories, and what sort of information to push into the background. To change levels is to change the foregrounding and backgrounding of information for different representational and pragmatic purposes.

**Keywords:** Levels of abstraction; levels of organization; levels of analysis; levels of scale; idealization; abstraction; foregrounding; backgrounding

What does it mean for two things to be on the same, or different, levels? In many colloquial everyday contexts, the answer can be relatively intuitive and straightforward. Being on the 3rd or 4th *level* of an apartment building is to be in a different spatial location within a layered physical structure. For Eric to be at the AssistantProfessorlevel as opposed to the Associate Professor levelis for Eric to have a different role within a socially defined institution.

However, in the context of scientific theorizing, the question of what it means for things to be on the same or different levels becomes somewhat more complicated and less apparent. Both phenomena, as well as our *scientific theories* *about* phenomena, are commonly demarcated in terms of levels. And yet it is not obvious what it means for there to be different levels of theories, or different levels of phenomena. In recent years, philosophers of science have attempted to clarify what levels are, and what role levels-talk has (if any) within scientific practice.

In this paper, I propose a new framework for thinking about levels in science that can help diffuse some of these debates, as well as provide justification for the importance that levels play in scientific reasoning more generally. Specifically, I argue that levels are best understood as choices that working scientist make regarding how and why particular kinds of information are being foregrounded in their representations, while other kinds of information are pushed into the backgrounding. To change levels is to change the foregrounding and backgrounding of information in our representations for different representational and pragmatic purposes. This way of interpreting what levels are allows us to unify the various ways in which levels-talk is used to demarcate phenomena and theories in science, while also avoiding some of the problems that different interpretations of levels have faced in recent years.

In order to make this argument, I will divide this paper into four sections. In section 1, I examine current debates surrounding the different uses of “levels” in science, and the problems that each faces. I also explore why there are reasons to be skeptical that there is any connective tissue linking the different senses of levels together within a single framework. In section 2, I discuss the nature of foregrounding and backgrounding in scientific modeling. I outline the reasons why scientists must deliberately foreground and background very particular kinds of information within their representations depending on their goals and interests, as well as the different ways in which this process can occur. In section 3, I propose an account of levels in science based on this foundation of foregrounding and backgrounding, and what this sort of account entails. Finally, in section 4, I demonstrate how different senses of levels can all be unified under this one framework, and how this framework allows us to overcome the problems that various accounts of levels have faced.

1. Levels, levels, everywhere

Debates about levels in science have attracted a great deal of attention in recent years (e.g. Brooks 2017, 2019; Brooks & Eronen 2018; Craver 2015; DiFrisco 2017; Eliasmith 2013, p.80-83; Eronen 2015; Heil 2003; Kästner 2018; Kersten, West & Brook 2016; Kim 2002; List 2019; McGivern 2008; Potochnik & McGill 2012; Rueger & McGivern 2010; Thalos 2013). These debates range from attempting to catalog what the various senses of levels invoked in science are, to the metaphysical status of levels, to whether certain uses of the term “level” in science are problematic or ought to be abandoned. Some senses of levels are distinctly *metaphysical* in nature, suggesting that certain phenomena, or all reality itself, is layered or hierarchical in some way. Other senses of levels appear distinctly *epistemic* in nature, in which we distinguish our *theories* or representations *of* the world in terms of levels. These distinct senses of levels often do not neatly align with one another.

For instance, it is not uncommon to observe “levels” talk in science as a means of demarcating domains of science more generally. McGivern, for instance, notes that levels are commonly “used to demarcate disciplinary or sub-disciplinary boundaries in the sciences” (2008, p.37). In this regard, we might talk about the level of psychology versus the level of neuroscience, or the level of chemistry versus the level of physics. However, this sense of levels can be contrasted with a distinct sense of levels used to demarcate compositional relationships, where phenomena at one level is thought to be composed by phenomena at a lower level. This distinct *organizational* or *mereological* sense of levels, often called “levels of organization”, is used for purposes other than demarcating scientific domains. It is particularly common in ecology (e.g. Begon, Harper & Townsend 1986; Molles 2002; Ricklefs 2008. See Potochnik & McGill 2012 for discussion), and biology (Craver 2007, 2015; Bechtel 2008).

While this mereological sense of levels is distinctly metaphysical, intended to track *levels of phenomena*,we also find more epistemic senses of levels invoked in science. Different kinds of scientific models, for instance, are often distinguished in terms of their *level of detail* or *level of abstraction*. Under these accounts, levels are demarcated in terms of the amount of detail included in, or deliberately left out of, our scientific representations*.* The more detailed the representation, the higher the level of detail, and thus the lower the level of abstraction. Conversely, the more detail left out of the representation, the higher the level of abstraction and the lower the level of detail.

This is not the only epistemic sense of levels we find in science either. In other contexts, “levels of analysis” or “levels of understanding” are used to demarcate radically different ways of *interpreting* the same system for different purposes.[[1]](#footnote-1) David Marr (1982), for example, famously argued that we can analyze the human perceptual system at three different levels of understanding: the computational level, the algorithmic level, or the implementation level. Each of these are best thought of as different ways of *interpreting* the same system: one in terms of what problem the system is trying to solve, another in terms of the algorithm used to solve the problem, and the third in terms of the physical structure of the system that implements the algorithm. Under this view of levels, to change levels is to change the *perspective* that we adopt towards a given system. Just like levels of abstraction though, levels of analysis is a distinctly epistemic sense of levels that often does not align with metaphysical senses of levels, such as levels of organization or composition. As Churchland, Koch & Sejnowski note, “when we measure Marr’s three levels of analysis against levels of organization in the nervous system, the fit is poor and confusing” (1990, p.38).[[2]](#footnote-2)

Recent debates have explored whether each of these different senses of levels have genuine value to science, and whether some are incoherent or worth abandoning. Consider levels of organization. Oppenheim & Putnam (1958) famously argued that reality itself is hierarchical, with different domains of science intended to describe and categorize the different layers of reality. The natural kinds that exist on any one level of reality are entirely composed of the natural kinds existing on the level directly below it. This view of levels was so influential and entrenched that some critics have argued that most contemporary debates about levels in science implicitly invoke it, often without realizing it (Brooks 2017). We can find a version of this sort of view presupposed in scientific domains like ecology:

Indeed, talk of levels is particularly prominent in the field of ecology: nearly all textbooks use the idea that ecological organization is hierarchical as an organizing principle. In addition to Sadava et al.’s [ecology] book, Ricklefs’s The Economy of Nature (2008), possibly the most popular undergraduate ecology textbook, has an introductory chapter with a description and visual representation of the levels of organization, then has book sections in order of Life and the Physical Environment (basically physiological ecology) followed by Individuals, Populations, Species Interactions, Communities, and finally Ecosystems. (Potochnik & McGill 2012, p.121-122)

However, this idea that all of reality is structured in terms of levels of organization has been roundly criticized over the years (e.g. Guttman 1976; Kim 2002; Heil 2003; Bechtel 2008, p.142-145; Potochnik and McGill 2012; DiFrisco 2017). Potochnik & McGill, for instance, claim that…

…stratification into levels is not universal or discrete. Stratification is not discrete in that it is not the case that an object taken to be at some level *n* is composed of all and only parts at level *n – 1*. Stratification is not universal in that it is not the case that all objects taken to be at level *n* are composed of parts from the same levels *j, . . . , k*.

Likewise, DiFrisco (2017) argues that any attempt to develop a consistent account of reality that is mereologically stratified will always be susceptible to counter-examples. In light of these problems, some have proposed we adopt a more restricted sense of levels of organization. Instead of *all reality* being composed of levels of organization, only particular mechanistic systems are. In order to understand this more local sense of levels of organization, we must first understand what a mechanistic system is taken to be.

Mechanistic systems are understood as collections of entities or parts organized in very particular ways to produce phenomena (Machamer, Darden & Craver 2000; Craver 2007; Bechtel 2008; Craver & Darden 2013; Hochstein 2016a). The parts that make up a mechanistic system can often themselves be complex mechanisms, which can be decomposed even further into additional sets of parts and operations. This results in a compositional hierarchy where mechanisms are embedded within larger mechanisms, resulting a clear sense of organizational levels (for more details, see: Craver 2007, 2015; Bechtel 2008). However, under this account, it makes no sense to ask if two unrelated mechanistic systems are, or are not, on the same level (since neither is a compositional part of the other).

Yet even this more restrictive sense of levels of organization is not without its problems (see: Eronen 2015, Kästner 2018). Eronen (2015), for instance, notes that this local mechanistic sense of compositional levels cannot consistently determine whether the parts of different sub-mechanisms within the same overarching mechanistic system count as being on the same level or not. On the one hand, the different parts belong to different sub-mechanisms, implying that they cannot be compared in terms of levels (since we cannot make sense of levels across mechanisms), on the other hand, both parts may function the same way and perform the same role within the system, implying that they *are* operating on the same level. As he puts it:

If we adopt this approach, only direct components of the same mechanism can be at the same level. Direct components of two different components can never be at the same level. [...] There are many cases where the subcomponents of the different components are exactly the same types of things—consider for example the fact that there are exactly the same kinds of cGMP-gated Na?-channels in both rod cells and cone cells. Furthermore, subcomponents of different components often causally interact. Thus, one outcome of the stronger form of the same-level criterion is that the same types of things that are playing the same role in the same overall mechanism, and that potentially causally interact with each other, are often not at the same level. (2015, p.50)

Eronen ultimately concludes that there is no way to definitively determine if subcomponents of a mechanism are ever on the same level or not. Others, like Kästner (2018), propose that we cannot overcome this problem by developing a coherent account of levels, and must instead supplement levels-talk with the notion of *epistemic* *perspectives*. These epistemic perspectives are ultimately determined by the background theories, practices, and tools, used by working scientists, and not by any objective fact about the mechanistic system itself. In her words:

If we analyze the situation in terms of epistemic perspectives […] we can conceive of mechanisms in terms of observations made from specific epistemic perspectives. We can thus decipher talk of levels in the context of mechanistic explanations as talk of epistemic perspectives. Thus understood, we immediately gain a way of assessing whether two entities A and B are “at the same level”. They are, if and only if A and B can both be observed from the same epistemic perspective. What is and what is not “at the same level” thus becomes a question that can be answered by close consideration of the skills, tools, and methodologies scientists employ for a given observation, the paradigms and experimental protocols they follow, the taxonomies they use and the background theories in light of which they design and evaluate their experiments. (2018, p74)

Others have proposed that talk of “levels of organization” (either globally, in terms of all reality, or locally, in terms of individual mechanisms) should be abandoned entirely and replaced instead with the idea of levels of *scale* (Potochnik & McGill 2012). The idea behind levels of scale is that many kinds of objects and processes in nature exist at particular sizes or scales, and tend to interact with other processes of similar size and scale (see: Churchland & Sejnowski 1988; Wimsatt 1994; Rueger and McGivern 2010). Wimsatt, for instance, argues that levels are “constituted by families of entities usually of comparable size and dynamical properties, which characteristically interact primarily with one another, and which, taken together, give an apparent rough closure over a range of phenomena and regularities” (1994, p. 225). The problem with this notion of levels is that objects at different scales can, and do, interact (See Bechtel 2008, p.142-145). Similarly, Potochnik & McGill argue that since scale is a continuum and not naturally carved into distinct strata, we cannot think of scale in terms of levels, but instead only as “quasi-levels”. In their words:

That different treatments succeed at different scales offers a way to demarcate what one might term “quasi levels.” In some respects, quasi levels are similar to classic levels: cells occur on a scale of microns to millimeters, while tissues are typically millimeters to decimeters; organisms (vertebrate and angiosperm, at least) are centimeters to many meters; ecosystems are measured in kilometers; and the biosphere is much larger still. Yet the concept of scale and the demarcation of quasi levels that it allows differ from the classical concept in fundamental ways. Most basically, scale is continuous, whereas levels are discrete. (2012, p.135)

Potochnik & McGill ultimately conclude that “there is therefore no expectation that a successful demarcation of quasi levels has ontological significance or even significance for unrelated phenomena” (2012, p.136).

Similar worries face the way in which we demarcate levels *qua* scientific domains. Where does psychology end, and neuroscience begin, for instance? Is cognitive neuropsychology on the same level as psychology, or neuroscience? Is it on both? Neither? What about the field of chemical physics? Or consider levels of abstraction. Any two descriptions that are not identical will leave out different kinds of details, suggesting that no two sentences could ever be on the same level of abstraction. And so what value is gained from talking in terms of levels?

These disputes have led some philosophers to conclude that the very concept of “levels” in science is ultimately confused and unhelpful. As such, we ought to jettison the concept from scientific theorizing entirely, replacing it with more suitable notions (e.g. Guttman 1976; Thalos 2013). In response, philosophers like Carl Craver have argued that this sort of eliminativist solution is impractical and unfeasible given how deeply ingrained the levels metaphor is to human reasoning:

The suggestion that we might be better off abandoning the levels metaphor is about as likely to win converts as the suggestion that we should abandon metaphors involving weight or spatial inclusion. These metaphors are too basic to how we organize the world to seriously recommend that they could or should be stricken from thought and expression. (2015, p. 2)

Instead of eliminating the concept of levels outright, Craver proposes that we grant that various senses of “levels” can all be scientifically valuable under very particular and limited circumstances, but we must be cautious not to equivocate between the different senses.[[3]](#footnote-3) He argues that there is nothing that unifies the different senses of “levels”, and that we ought to be descriptive pluralists when it comes to the term. The term is simply a “promiscuously applied” metaphor; one which “is applied usefully in many contexts to describe different relata, different relations, and different senses in which items might be located at a given level.” (2015, p.23) As such,

…there can be no single verdict concerning the utility or conceptual soundness of the levels metaphor simpliciter. The metaphor must be evaluated and used with caution, especially when it is called on to settle disputes about the character of science and the metaphysical structure of the world. (Craver 2015, p.2)

Contra Craver, I propose that there really might be a single verdict concerning the utility or conceptual soundness of the levels metaphor simpliciter; moreover, that the appropriate account of levels can help to unify the various epistemic and metaphysical senses of levels, as well as diffuse some of the current debates about levels. In order to demonstrate this however, it is first necessary to take a small detour and talk for a moment about why scientists must be selective about the sort of information they choose to explicitly include, or leave out of, their models and theories.

2. Foregrounding and Backgrounding

Depending on the sort of question scientists are attempting to answer, they must make deliberate choices about the sort of information to include in their models, theories, and representations, and the sort of information to leave out. This decision is influenced by a number of factors.

First, including too much information about a given phenomenon in one’s representation can often be counter-productive, obscuring the very patterns or regularities they are trying to represent and study. By including too many accurate details into the representation, we make it impossible to parse the patterns that are of interest, from those that are not. It is only by being selective in the information we include that we can effectively see what we are trying to represent without getting bogged down by excessive details. In such cases filtering out information, often by way of abstraction (leaving out details that are irrelevant, or which get in the way) and idealization (deliberately oversimplifying the phenomenon to emphasize the features of interest) is required in order to allow us to track the patterns and regularities we care about. As Robert Batterman argues, “idealizations trade on the fact that in many instances ‘overly simple’ model equations can better explain the most salient features of a phenomenon than can a more detailed less idealized model. [In these cases], adding more details counts as explanatory noise - noise that often obscures or completely hides the features of interest.”(2010, p.17) Angela Potochnik makes a similar argument, noting that:

The limited powers of human beings and especially of our cognition, when faced with incredibly complex phenomena, are accommodated with the help of idealizations, but idealizations that are specific to their purposes. Idealizations that further understanding of one feature of a phenomenon tend to obscure other features, and they cannot be expected to serve other aims, such as accurate prediction, equally well. This scenario results in focus on one particular scientific aim (at a time) to the exclusion of others and results in a divide-and-conquer approach, where scientific products are tailored to their precise aims. In order to successfully predict, or to represent a certain element of the causal structure, or to provide quick guidance for policy, one often must sacrifice other aims. (2015, p.76)

There are also more mundane reasons why scientists create models which selectively focus on certain details (thereby *foregrounding* this information), while pushing other kinds of details into the background. One is limitations on cost and resources. Dropping certain kinds of details, or simplifying our models, can free up representational resources which can then be used to more effectively represent other features or details we are more interested in (see: Eliasmith & Trujillo 2014).

And so scientists make deliberate decisions regarding what information to foreground and background in their models and theories for representational reasons (i.e. the appropriate sort of foregrounding and backgrounding is needed to accurately identify the phenomenon of interest, and to distinguish it from patterns and regularities that may obfuscate our understanding of it), as well as practical reasons (i.e. foregrounding and backgrounding is needed to effectively represent the phenomenon when working with limited time, resources, and computational power). With this understanding of *why* foregrounding and backgrounding is commonly employed within scientific practice, it is worth taking a moment to explore the different ways that this process of foregrounding and backgrounding can occur.

By pushing information that is of less interest to us “into the background”, we might be doing a number of different things. In some cases, the information is simply abstracted away and not considered. In the case of the Ideal Gas Law, for instance, we simply leave out details about the volume of the individual particles that make up the gas, since this information does not materially impact our calculations for how gases will behave at moderate pressure and temperature values. In other cases, by pushing information into the background, we do not *explicitly* include the information in the representation, but this information is still *implicitly* built into the boundary conditions of the model, and its applications.

To illustrate, consider two different kinds of cases. In Newtonian Mechanics, we might omit friction from our model of a ball rolling down an inclined plane. By ignoring this information, our model of the ball’s behaviour will not be accurate, since friction changes the behaviour of the ball as it moves down the plane. Here the information is dropped entirely, and in doing so changes our account of how the modeled system behaves. However, since the effects of friction are often negligible given our scientific purposes, this information can be dropped without significant consequence. Next, consider a second case. Many large-scale brain models work with *point neurons*, representations that treat neurons as single mathematical points with no spatial or morphological characteristics, just input/output relations. Such models are often used to approximate the input/output relations of real neurons, but not to study the morphology of neurons. As such, they leave out structural details of the neuron to free up computational resources. The problem is that the spatial and morphological properties of neurons directly determine their input/output relations. Calculating how our modeled neurons would behave if they had no morphological or spatial characteristics would yield behaviours that would differ wildly from those of real neurons, making them useless for our modeling purposes. And so instead of just dropping these morphological details entirely (as with friction in the Newtonian Mechanics case), we tune the behaviour of our point neurons to fit with the statistical behaviour of real neurons with specific morphologies. In this respect, accurate information about the morphological and spatial characteristics of the neurons are pushed into the background not by being left out of the model entirely, but by *implicitly* framing and structuring the behaviour of the point neurons which are foregrounded in the model. In other words, when we calculate the behaviour of the ball rolling down the hill, we calculate its behaviour without friction. However, when we calculate the behaviour of the point neuron, we don’t do so without implicitly taking into account the spatial and morphological details of the neuron, otherwise the firing patterns that we would generate would be radically different. Only neurons with very particular morphologies will have those behaviours, and thus we implicitly presuppose those morphological details when building those behaviours into the point neurons.

In other cases, we might push information into the background by physically removing the actual system from influences that exist in the real world (Cartwright 1999; Datteri & Laudisa 2012; Hochstein 2016c). This often involves studying how a system behaves in isolated laboratory conditions. While scientists are aware that real world environmental causes and influences change the behaviour of the system, this information may not be the primary concern of the scientist in a given experiment (if, for instance, they are more interested in studying structural or architectural features of the system as opposed to its behaviour). Thus, this information can be pushed into the background by physically isolating the system from such environmental influences.

Another method of backgrounding information is by deliberately distorting or misrepresenting features of the phenomenon that are not our primary interest in order to better represent the features of the phenomenon we care about. Unlike in the case of abstraction, we do not merely leave out information, but deliberate describe features of the phenomenon in incorrect ways. For instance, if we wish to characterize what traits natural selection is most likely to act on in a given population, we might do so by describing the population size as infinitely large. In this way, by working with infinite populations sizes, “stochastic effects [on gene frequencies can be] safely ignored, [and] changes in gene frequencies can be tracked by concentrating solely on the action of selection” (Woods & Rosales 2010, p.5). Biologists are, of course, aware that such effects influence the evolutionary trajectory of real populations, but because that is not always their primary interest, this information can be pushed into the background by idealizing population sizes.

With an understanding of the essential role that foregrounding and backgrounding plays in scientific practice, and the different ways in which such a process occurs, we now have the appropriate groundwork in place to develop a unified theory of levels in science.

3. A New Conception of Levels

So how does all this relate to our understanding of levels? I propose that the foregrounding and backgrounding of information can be used as the foundation of a new account of levels in science; one which can not only unify numerous epistemic and metaphysical senses of levels, but which can also help to address some of the problems that different accounts of levels have faced. As discussed in Section 2, there are regularities and patterns in nature that can only be successfully represented, predicted, or understood, by employing models and theories which foreground and background information in particular ways. With this in mind, the scientific use of the term “levels” should be reconceptualized as a linguistic cue that scientists can invoke in order to signal to their audience that they are foregrounding and backgrounding very particular kinds of information in their models and theories for particular representational or practical purposes. This way, the consumer of the representation understands what sort of information they should expect to see and not see, what they will be expected to focus their attention on, what sorts of patterns are being searched for, and what information they can safely ignore. To talk about different levels in science is thereby to talk about different models and theories that are foregrounding and backgrounding information in different ways for different purposes.

This view of levels shares some key features with other recent views in philosophy of science, but deviates from them in some essential ways. Consider, for instance, talk of “perspectives” in science (e.g. Giere 2006; Kästner 2018). Kästner (2018) defines an epistemic perspective in the following way:

Put briefly, epistemic perspectives can be considered as filters offering different ways of accessing and describing things in the world. The tools and paradigms a researcher uses, her skills, the background theories she assumes, as well as her explanatory concerns jointly determine her epistemic perspective. (p.69)

Ronald Giere (2006) defends a similar view of perspectives. According to Giere, we can think of the Aristotelian/Ptolemaic view of planetary motion, and the Copernican/Newtonian view, as different theoretical perspectives (2006, p.94); likewise with Special Relativity and Quantum Theory in physics (2006, p.92).

The notion of a “perspective” as defended by Giere and Kästner captures some of the same intuitions as the view of levels being defended here. A change in epistemic perspective can count as a change in levels under the account of levels being proposed. But this is not always the case. To understand why, we must understand what makes a change in epistemic perspectives so valuable to science. One reason we must change epistemic perspectives is precisely because such a shift in perspective can sometimes be the only way we can effectively construct models and theories that foreground and background the right *kind* of information needed to identify certain kinds of patterns and regularities in nature.

To illustrate, consider *dynamical systems theory* as it is employed within cognitive science (Thelen & Smith 1994; Van Gelder & Port 1995; Eliasmith 1996; Ross 2015). A dynamical system is a complex system that is in a constant state of change. In order to identify patterns or regularities in the behaviour of such ever-changing systems, we must employ a particular kind of mathematical formalism: differential equations. Or for a more specific definition:

The branch of mathematics called dynamical systems theory describes the natural world with essentially geometrical concepts. Concepts commonly employed by dynamicists include: state space, path or trajectory, topology, and attractor. The state space of a system is simply the space defined by the set of all possible states that the system could ever pass through. A trajectory plots a particular succession of states through the state space and is commonly equated with the behavior of the system. The topology of the state space describes the “attractive” properties of all points of the state space. Finally, an attractor is a point or path in the state space towards which the trajectory will tend when in the neighborhood of that attractor. Employing these concepts, dynamicists can attempt to predict the behavior of a cognitive system if they are given the set of governing equations (which will define the state space, topology and attractors) and a state on the trajectory. The fact that dynamical systems theory employs a novel set of metaphors for thinking about cognition is paramount. (Eliasmith 1996, p.443-444)

In this respect, we can think of dynamical systems theory as a particular kind of epistemic perspective we can take towards cognitive systems. But why should we adopt this perspective? Because there are certain kinds of patterns that exist within the phenomenon: dynamical patterns in how the system evolves and changes over time. In order to effectively identify these patterns of dynamic change, the use of a particular mathematical formalism (i.e. differential equations) is required. This particular formalism foregrounds particular kinds of information, while backgrounding others, in order to more effectively represent the way the system is likely to change over time (for more, see: Ross 2015). However, while this formalism is ideal for identifying certain dynamical patterns, it is unhelpful for identifying other patterns. There are all kinds of *statistical* patterns that exist in nature, for instance. To identify these patterns, a different kind of conceptual framework (i.e. a different “perspective”) is required. In such cases, we apply the conceptual resources of *probability theory* to construct a statistical model of the system. A statistical model foregrounds and backgrounds very different kinds of information than does a dynamical model, but in doing so is more effective at identifying statistical patterns that exist in nature.

And so changes in perspective (e.g. statistical vs dynamical) are important because they allow us to foreground and background information in very particular ways needed to see different patterns and regularities. In this regard, the theory of levels on offer can account for the explanatory and representational value of adopting different perspectives. That being said, we must be careful not to think of levels strictly in terms of perspectives. While changing epistemic perspectives is *one* way in which we can foreground and background different kinds of information in our models and theories, not all cases of changing levels require a change in perspective of this sort. For instance, one can vary the degree of detail in one’s models or theories while still working within the confines of a single epistemic perspective. In such cases, the foregrounding and backgrounding of information needed to identify different patterns in nature does not require a dramatic shift in our epistemic perspective. In this way, it would be a mistake to define levels in terms of epistemic perspectives, but we can accommodate the insights of epistemic perspectives within the new framework of levels being proposed.

This view of levels likewise shares insights with more pragmatic accounts of scientific modeling. Consider Eliasmith’s notion of “descriptive pragmatism”. According to Eliasmith…

Sometimes we may describe a system as a person without much consideration of their relationship to individual particles. Other times we may be concerned about the decomposition of a biological person, leading to what looks like a kind of reductive description. The reasons for preferring one such description over another can be largely practical: in one case we need to predict the overall behavior of the whole system; in another we need to explain how changes in a component influence complex interactions. [...] I am suggesting that levels should be taken as pragmatically identified sets of descriptions that share assumptions. Perhaps it is useful to call this position “descriptive pragmatism” for short. (2013, p.80-81)

This idea certainly shares a lot in spirit with the idea of levels being proposed here. However, Eliasmith’s account is left extremely vague, as he himself acknowledges. Given that his project is not focused on the nature of levels itself, he merely makes a passing comment before leaving the topic aside:

I should note that I in no way take this brief discussion to sufficiently specify a new characterization of levels. There are many, much deeper considerations of levels that I happily defer to others (e.g., Bechtel, 2008; Craver, 2007; Hochstein, 2011). My purpose is to clarify what general characterization of levels lies behind my use of the term throughout the book, so as to avoid confusion about what I might mean. (Eliasmith 2013, p.81)

The view of levels I defend here builds on similar themes, but is intended to explain how a new characterization of levels might incorporate similar kinds of insights.

Similarly, the view of levels being proposed acknowledges the important role that idealization and abstraction plays within scientific reasoning (e.g. Cartwright 1999; Elgin 2004; Longino 2006; Batterman 2010; Woods & Rosales 2010; Eliasmith & Trujillo 2014; Potochnik 2015; Hochstein 2016b, 2016c). Our cognitive limitations, and the particular representational tools we use, mean that certain patterns or regularities in nature may only be *visible* *or* *understandable to us* if presented in a way which foregrounds and backgrounds information in particular ways. Moreover, since foregrounding and backgrounding different information is essential to effectively represent and/or understand different patterns in nature (as foregrounding *too much*, or the *wrong kind* of, information can obscure certain patterns, while foregrounding and backgrounding different information will obscure others), scientists often must change levels when studying different aspects of the same complex phenomenon (e.g. Marr 1982; Hochstein 2016c). In this regard, working at multiple levels is essential to scientific practice.

One potential concern worth noting is: how exactly do we systematically determine if two models or theories are working on the same level or not under this account? After all, any two models which do not foreground/background exactly the same information will appear to count as being on different levels according to this view. Does this imply that only identical descriptions can ever count as being on the same level? Does this invalidate the notion of levels being proposed?

The first thing to note is that this problem is not unique to the view of levels on offer here. The same criticism applies to levels of *abstraction*. As any two descriptions which are not identical will be abstracting different kinds of information, suggesting that they operate on different levels of abstraction. Similarly, levels of scale likewise face this problem, as any two objects which are not the exact same size may count as operating on different scales.[[4]](#footnote-4)

The solution to this problem is to understand the social-pragmatic role that levels-talk plays. The purpose of invoking “levels” in science is to indicate to an audience that certain kinds of information are being foregrounded and backgrounded *in light of a particular representational goal* (e.g. identifying one pattern or regularity as opposed to another). In this respect, whether two descriptions are on different levels can depend on the goals and interests of the working scientist. Consider levels of abstraction. Any two descriptions which are not identical can be thought of as being on different levels. So what is the reason for distinguishing models in terms of levels of abstraction? The reason is that some differences in terms of what is being abstracted are noteworthy for a given representational purpose, while others are not. For instance, we might argue that two descriptions of a particular neural mechanism which vary only slightly in terms of the structural details they provide are technically on different levels of abstraction, but if the difference between the two is not of interest or value to working scientists (e.g, the difference in detail has no bearing on our ability to represent the pattern or regularity being studied), then there is no reason to treat these as different levels of abstraction. But if certain patterns in nature can only be seen by deliberately leaving out certain kinds of information that other models include, and which is often thought to be relevant, then this justifies treating them as different levels. So for instance, the use of a dynamical model in cognitive science often requires abstracting away from the causal-mechanical details of that system in order to effectively identify the dynamical pattern being studied (e.g. Ross 2015). In this respect, one may wish to call attention to the fact that all kinds of causal variables relevant to the production of the system’s behaviour are being intentionally left out given the representational goal of identifying a particular pattern (thus justifying out treatment of this as a different level). Thus, whether two descriptions operate on the same, or different, levels often depends on what the models are being used to represent, and what the model-builder thinks that the consumer of the representation expects.

The same applies to issues of scale. Two objects that differ in terms of size may technically not be at the same “scale”, but if the difference isn’t relevant for our purposes, then we have no reason to treat these differences as sufficient to constitute a different level. Put simply, whether objects are on the same, or different, levels is not determined only by the structure of the world alone, but in part by what scientists are trying to signal to their audience about what information is noteworthy given their representational purposes.

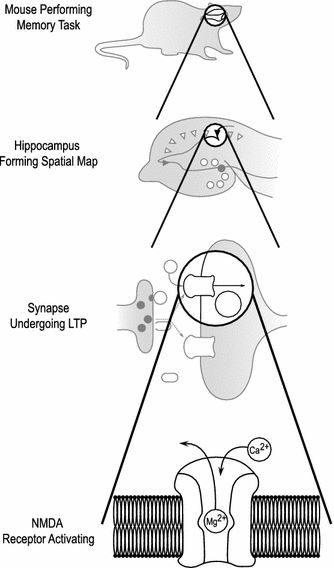
This might raise concerns about how systematic this view of levels really is. If what we have are radically different methods of foregrounding and backgrounding information (e.g. abstraction, idealization, change in perspective, isolation, etc) for different purposes, then in what regard are these all part of a single unified framework of levels? Why assume there is any overarching account of levels at work here, as opposed to merely different methods of foregrounding and backgrounding information? The answer is that it is not the *method by which* information is foregrounded and backgrounded that unifies these accounts under a single theory of level, but the fact that working scientists have a means of informing the consumers of their representation that there are particular representational reasons *why* certain kinds of foregrounding/backgrounding is being employed given the patterns and regularities being studied.

There are some noteworthy implications that follow from this. First, levels may not be stable over time. As science progresses, we might find that a particular “level” (i.e. a particular foregrounding and backgrounding of information) which we thought was needed to identify a certain pattern or regularity in nature was misguided. We might have misconstrued what the pattern or regularity was, suggesting that we needn’t adopt this level for any scientific purpose (i.e. the “alchemical level” may be just such an example). Conversely, we might have to construct new levels in science as we discover new kinds of patterns in nature that require different sorts of information to be foregrounded and backgrounded. In this regard, we shouldn’t expect levels to map cleanly onto stable ontological strata in nature.

4. Reinterpreting Old Levels in New Ways

In order to further explain this view of levels, let us explore how different metaphysical and epistemic senses of levels can be subsumed under this account, and how some of the problems that plagued these accounts can now be addressed. To start, let us return to levels of organization. According to one view, only individual mechanisms are structured in terms of levels of organization. Comparing levels *across* mechanisms has no meaning. According to the other view, all of reality can be organized in terms of levels of organization. Let’s look at both views in kind.

Let us begin with the *mechanistic* sense of levels employed in science. The organizational nature of mechanistic systems suggests that mechanisms themselves are hierarchically structured, as we have mechanisms which are embedded in larger mechanisms, which are embedded in even larger mechanisms. At first blush, this mechanistic sense of levels may seem to be at odds with the view of levels being proposed. After all, it is the mechanism out in the world that is thought to be multi-level, not our models and theories of it. In other words, it is the mechanism itself that operates at different metaphysical layers, and this is not a result of the way we foregrounded and backgrounded information about it. To see how the account of levels I wish to defend applies in this case, consider **Fig. 1** (taken from Craver & Darden 2013):



[**Fig. 1**: Example of a multi-level mechanism (Craver & Darden 2013)]

Here we see one mechanism (NMDA Receptor Activation) as a constitutive part of a larger mechanism (Synapse Undergoing LTP), which in term is a part of an even larger mechanism (Hippocampus Forming Spatial Map), and so on. This image certainly makes the system *look* metaphysically hierarchical, but this is in part because it is drawn so that the picture of the embedded mechanism is underneath the picture of larger mechanism of which it is a part. But let’s keep this same image, and change the metaphor slightly. Instead of “going up” or “going down” metaphysical strata, let’s instead think of this in terms of *zooming in* or *zooming out*, in the way one might with a camera.

Instead of the hippocampus operating at a different metaphysical layer than the mouse of which it is a part, what we have is a case in which by “going down” a level from the rat as a whole to the hippocampus, we are zooming in on the rat’s hippocampus. In doing so, the way in which the hippocampus is situated within the surrounding context is pushed “out of frame”. We know that the hippocampus is a part of an integrated brain, but we simply aren’t interested in how the hippocampus is integrated into the larger surrounding system. Moreover, by zooming in we can see more details regarding the structure and operations of the hippocampus in particular that we couldn’t see when we were “zoomed out”. Thus by zooming in on the hippocampus, the contextual information about the hippocampus’s place within the rat’s brain is pushed into the background, but other details are moved into the foreground. On the other hand, by zooming out we can better see how the hippocampus is situated within the brain (thereby pushing these organizational details into the foreground), but we can no longer see fine-grained details regarding the mechanistic features of the hippocampus (pushing those details into the background).[[5]](#footnote-5) While systems can often be embedded in larger environmental contexts, this does not necessarily mean we should think of them as operating on different *strata* or metaphysical *layers*. Instead of “up” or “down” in a *metaphysical* sense, we have “wider” and “narrower” descriptions of a system and its organizational relationships to its surrounding environment. Put another way, to go “down” or “up” a mechanistic level is to make a choice about what kind of information to foreground and background when describing various features of complex integrated mechanistic systems.

Notice how this idea of levels is compatible with the metaphysical mereological fact that the hippocampus *is* a constitutive part of the rat, that synapses undergoing LTP *are* constitutive parts of the hippocampus, and so on. But to differentiate these in terms of *levels* is to make a conscious decision as to which of these features to explicitly focus on in our representation, and which to push into the background. Thus the mechanistic sense of levels can be subsumed under this new account of levels without losing the important metaphysical insight that systems can be embedded within larger systems.

Now let us consider the problem that mechanistic accounts of levels have faced. How do we determine if two subcomponents of the same mechanism are on the same, or different, levels? Are the sodium channels in two different neurons which are sub-components of the same overall mechanistic system on the *same* level, or *different* levels? If we assume that levels are strictly metaphysically determined by the organizational features of the system, then there must be a clear answer. However, under the account proposed here, both may be true depending on which patterns or regularities we wish to identify.[[6]](#footnote-6)

We might, for instance, be interested in the conductance properties shared by sodium channels of various kinds of neurons (e.g. Hodgkin & Huxley 1952). In which case, our scientific models might foreground this sort of information, while backgrounding information about the differences that exist between the two neurons. In such a case, we can easily talk of the sodium channels of the two neurons operating on the same level. Conversely, if we are interested in the sodium channels of a single neuron and its place within a particular system, then talking about it operating on the same “level” as the sodium channel of a different neuron would be unhelpful. Both cases can be accommodated by understanding what sorts of patterns and regularities we wish to identify, and what sort of foregrounding and backgrounding is needed to identify them.

Next, consider the idea that reality itself can be hierarchically ordered into levels of organization. To illustrate, it is not uncommon to talk of phenomena existing at the “molecular level”. This way of talking implies that all molecular phenomena exist on the same organizational level of reality. Eronen, for example, highlights this point by reference to a particular physiology textbook written by Kandel:

In a section titled ‘‘Nerve Cells Differ Most at the Molecular Level’’, Kandel writes: ‘‘because the nervous system has so many cell types and variations at the molecular level, it is susceptible to more diseases (psychiatric as well as neurological) than any other organ of the body’’ (Kandel et al. 33). Kandel is describing the general idea that the nervous system is susceptible to a broader range of diseases than other organs because nerve cells vary greatly at the molecular level. […] The term ‘molecular level’ seems to be referring to a general level of organization, in the style of Oppenheim and Putnam. (2015, p.47)

As noted, there are numerous problems that have plagued this sort of global mereological view of levels of organization. Put simply, the objects of one level of reality are frequently not neatly decomposable into objects on the level directly beneath (Kim 2002; Potochnik and McGill 2012). Moreover, it becomes impossible to consistently situate objects on only a single organizational level of reality (DiFrisco 2017).

These sorts of problems, however, present themselves only if we assume that levels of composition must conform to certain criteria; specifically, the criteria originally laid down by Oppenheim& Putnam in their 1958 paper (see: Brooks 2017). Under the account of levels provided here, however, it is our foregrounding and backgrounding practices that determine levels, not the structure of reality alone. Just as with levels of mechanisms, to work at a particular “level of organization” in a global sense is to foreground information about certain phenomena, while backgrounding information about the mereological parts and operations that may constitute them, or the way they may be integrated within much larger systems.

To illustrate, let us focus on *why* talking about the “molecular level” is important. The idea is that there is a certain pattern or regularity in nature (in this case, our susceptibility to a broad range of diseases) that is best identified, studied, and understood when we foreground particular *molecular* details of the central nervous system, while backgrounding all kinds of information about how these molecular components of the system may be instantiated. As such, the question of whether all molecular phenomena are neatly composed of objects “one level lower” is simply irrelevant, as is the problem of whether all molecular objects can be shown to be on only one metaphysical layer of reality. Instead, the term “molecular level” is intended to indicate to an audience that it is particular kinds of molecular information that is to be foregrounded in our representations, because this is what is required to represent the regularity we seek to understand.

Next, let us consider levels of *scale*, since this is the view of levels that Potochnik & McGill (2012) have proposed we replace levels of organization with. The account of levels being defended here can likewise accommodate levels of scale by noting that certain patterns in nature (e.g. planetary motions and orbits) are best identified and characterized by foregrounding information about objects of particular sizes (e.g. planetary bodies as opposed to, say, microorganisms). Information about objects of a much smaller size will not be relevant to seeing the particular celestial pattern we wish to see, and so will only add noise to our representation if included; so we can push such details into the background. Note that this view of levels does not deny that objects of different scales can and do causally interact all the time. The issue is that depending on what we wish to study and learn about, information about objects of certain sizes may simply not be relevant to include in our representations, while others are.

But if this is true, what does this say about the relation between “levels” and “quasi-levels”? Recall Potochnik & McGill’s worry that “the concept of scale and the demarcation of quasi levels that it allows differ from the classical concept [of levels] in fundamental ways. Most basically, scale is continuous, whereas levels are discrete” (2012, p.135). The underlying intuition here is that because size is a continuum, the division of nature into discrete levels of scale is not out there to be discovered, but imposed on the world by us. As such, the traditional concept of levels does not apply, as levels are supposed to be discrete. Moreover, genuine levels “elevates part-whole relationships to prominence, while scale is fully independent of part-whole relationships” (2012, p.136). The problem with this demarcation between levels and quasi-levels is that it implicitly invokes the Oppenheim & Putnam account as its primary guide for determining what counts as a legitimate use of “levels”, and what doesn’t (i.e. that “levels” denote discrete layers of reality, and that the objects at one level are always mereologically composed of the objects on the level directly beneath). I propose that common and legitimate uses of “levels” require neither that levels be ontologically or metaphysically discrete, or that they involve part-whole relations.

To illustrate with a colloquial example, consider the volume level on your television. Volume, just like size/scale, is a continuum. Sound does not cleanly divide into discrete volume strata independent of human classification and convention. Moreover, higher volume levels do not relate to lower volume levels by part-whole relations. Yet, we don’t consider this use of “levels” to be inappropriate, metaphorical, or merely “quasi”. The same applies to levels of abstraction. Abstraction likewise exists on a continuum, and is not determined by part-whole relations. These uses of “levels” only seem problematic when we use Oppenheim & Putnam as our arbiters for what counts as a legitimate “level” and what doesn’t. But I propose that the use of “levels” in daily life and in science does not require we make any such concessions to them (for more on this point, see: Brooks 2017). In this regard, we can consider levels of scale to be genuine levels under the view being defended, and not merely “quasi-levels”.

What about the other senses of levels discussed so far? How can they be subsumed under the new framework of levels being proposed? Understanding levels of *abstraction* or levels of *detail* is easily accommodated by this new framework, since levels of abstraction are typically characterized in terms of the quantity of information dropped from, or included in, a given model or representation. This is, in itself, a form of foregrounding and background. In fact, it might be tempting to view the account of levels being defended as nothing over and above the idea of “levels of abstraction”, but we must be cautious here. *One* way of backgrounding information is by abstracting it away. But there are other ways of pushing information into the background that do not straightforwardly involve simply dropping details from the model entirely. For instance, let us return to David Marr’s three levels. Specifically, let us compare the computationallevel with the implementation level. The computational level describes *what sort of problem* the visual system is trying to solve. Meanwhile, the implementation level describes the physical mechanisms and structures that compose the system. With this understanding of levels, it would be a mistake to suggest that by merely dropping details of the structure of the system it tells us what problem the system is trying to solve. The problem being solved by a system is not merely an abstract description of the structure of that system. Indeed, they involve adopting different interpretations of the system. This shift in perspective is required in order to foreground and background different kinds of information about the same target system in order to learn different things about it, but is not achieved simply by means of abstraction.

Keeping with this notion of interpretation, the story of levels on offer can also make sense of levels of *analysis* or *understanding*. Levels of analysis are invoked in science when our ability to successfully represent certain kinds of patterns requires that we adopt a very particular kind of conceptual framework, formalism, or perspective in order to successfully foreground and background the appropriate information. This point is nicely illustrated with Giere (2006) and Kästner’s (2018) notion of epistemic perspectives. There are essential features of phenomena that cannot be analyzed from a single perspective on the system. In order to foreground certain essential information about the phenomenon, it requires changing the way in which we analyze or interpret the target system. This change in perspective is what allows the relevant foregrounding and backgrounding to occur.

Next, let’s consider the notion of levels as corresponding to scientific domains. The level of psychology versus the level of neuroscience, for instance. How can we make sense of such levels under the new framework? If “levels” is a linguistic cue used to indicate that one is foregrounding and backgrounding very particular kinds of information in one’s models, then how can we make sense of different domains conforming to different levels? After all, different models and theories within psychology will foreground and background information in different ways. As will different models and theories in neuroscience. And so under this new account, it would appear that we cannot even claim that models *within* a particular scientific domain are on the same level, let alone make sense of entire domains of science corresponding to distinct levels.

To account for this, consider that different scientific domains have traditionally employed distinct sets of representational tools for learning about the world, and study different (albeit often overlapping) phenomena. In this regard, domains of science are often very loosely defined and demarcated by what they are studying, and how. Psychology has traditionally been understood as a field that focuses on studying how people behave under various conditions, how people socially interact, solve problems, form communities, etc. However, scientific models and theories which attempt to characterize these behaviours often, by necessity, do not include detailed information regarding all physiological, genetic, and developmental mechanisms and processes which produce these behaviours. Psychologists are of course aware that such causal influences are present and relevant, but attempting to characterize complex human behaviour by including *all* causal variables (including neurological, physiological, socio-economic, historical, evolutionary, developmental, genetic, epigenetic, etc) would be both unfeasible and unhelpful. What is far more advantageous is to push such detailed causal information into the background so that the models and theories can focus instead on representing the particular patterns in behaviour that are of interest (for a more detailed defense of this idea, see: Hochstein 2016c). Thus, psychology as a field has traditionally tended to background certain kinds of information (i.e. complex physiological details) and foreground others (i.e. patterns in human behaviour, problem solving capacities, etc).

In a similar vein, neuroscience is often interested in characterizing neurological structures and processes, but often at the cost of including information about the kinds of complex social contexts in which the neurological system may be imbedded. For practical reasons, neuroscientists will often isolate a given neurological mechanisms from environmental influences under laboratory conditions to study its structure and behaviour (see: Datteri & Laudisa 2012). Likewise, many kinds of genetic and epigenetic influences are not included in neuroscientific models (Longino 2006). As such, the theories and models of neuroscience have *tended to* foreground and background different kinds of information than do models of other domains, like psychology and genetics. Of course, not all neuroscientific models will foreground or background exactly the same details, but historically, the different domains were defined in part by the *kinds* of information that they tended to foreground, and the kinds they’ve tended to background. The same is true of genetics, chemistry, physics, etc. This is how we get a very loose sense of levels conforming to scientific domains. The models and theories that belong to a certain domain cluster around their tendency to include certain types of information, and backgrounded other types. The fuzziness in domain boundaries stems from the fact that this historical tendency to foreground and background in particular ways was not a hard-and-fast rule. And so as technology has advanced, different domains have become capable of including information that has traditionally been considered the purview of other domains.

And so what do we say about models and theories that seem to transcend traditionally defined scientific domains? Is cognitive neuropsychology on the same level as psychology, or neuroscience? I propose that there is no fact of the matter to appeal to when dealing with fuzzy boundaries of scientific domains. There are different possible answers that would suffice here. One possible answer is that it *bridges both levels*. Why? Because it tends to foreground particular kinds of information that have historically been foregrounded exclusively by one domain in isolation of the other. And so by foregrounding both types of information in a single representation, it straddles both domains. Another possible answer is that there is a *new* level: the cognitive neuropsychology level. One that is neither the neuroscience level, nor the psychology level, because models and theories in this domain tend to foreground and background certain kinds of information that do not entirely line up with the way information has traditionally been foregrounded and background in psychology or neuroscience. But in either case, this is nicely accommodated by the new framework of levels being proposed. For a scientist to inform their audience that they are now operating at the cognitive neuropsychological level, or attempting to straddle the neuroscience and psychology levels, is to inform them that the models and theories being employed will tend to focus on *certain kinds of* information, and push into the background other kinds of information. And so the new theory of levels being proposed can explain both the underlying intuition that different domains operate at different levels, while also accounting for the fuzziness of the boundaries between those domains.

By demonstrating how these various senses of levels can all be subsumed under the same framework, it clarifies not only the view of levels on offer, but also demonstrates how the problems facing the different senses of levels can be overcome. Both epistemic and metaphysical senses of levels can be unified under the same framework given that levels are determined in part by the interests and goals of working scientists, and in part by the patterns and regularities that exist out in nature which influences how and why certain foregrounding and backgrounding is required.

5. Conclusion

In this paper I have proposed a unified theory of levels in science, one which can make sense of the myriad of ways that levels are invoked in scientific practice while simultaneously avoiding the problems and disputes that different senses of levels have garnered in isolation. I have likewise demonstrated why levels play an essential role in scientific reasoning. The need to foreground and background different kinds of information in our models and theories is essential to our ability to represent various kinds of regularities and patterns in nature, and to work within cognitive and practical limitations.

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1. This sense of levels is also sometimes referred to as “levels of explanation”. [↑](#footnote-ref-1)
2. For more on the distinction between metaphysical and epistemic senses of levels in science, see: Kersten, West & Brook 2016. [↑](#footnote-ref-2)
3. A similar idea is also defended by Kersten, West & Brook 2016. [↑](#footnote-ref-3)
4. This is one of the reasons that Potochnik & McGill (2012) suggest that we should think of levels of scale as merely “quasi-levels” instead of full-blooded levels. [↑](#footnote-ref-4)
5. For clarity, we must to be careful not to take this zooming metaphor *too* literally. Changing levels isn’t literally zooming in and out. After all, the sorts of information foregrounded and backgrounded by our models can vary in any number of different ways based on the choice of working scientists. “Zooming in” often implies going *smaller*, while zooming out implies going *larger*. But this is not always the case with the sense of levels proposed here. The zooming metaphor is only intended to intuitively illustrate how a compositional sense of levels need not be committed to literal metaphysical layers, only complex integrated systems that we can describe different parts of in isolate of others depending on what we wish to learn. [↑](#footnote-ref-5)
6. A similar sort of response is proposed by Kästner (2018), who argues that both are true from different *epistemic perspectives*. [↑](#footnote-ref-6)