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The significance of levels of organization for scientific research: A heuristic approach[1]

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ABSTRACT

The concept of 'levels of organization' has come under fire recently as being useless for scientific and philosophical purposes. In this paper, we show that 'levels' is actually a remarkably resilient and constructive conceptual tool that can be, and in fact is, used for a variety of purposes. To this effect, we articulate an account of the importance of the levels concept seen in light of its status as a major organizing concept of biology. We argue that the usefulness of 'levels' is best seen in the heuristic contributions the concept makes to treating and structuring scientific problems. We illustrate this with two examples from biological research.

1. Introduction

'Levels of organization' is a cosmopolitan term found throughout the natural (and particularly biological) sciences and in philosophy, and is used to express a wide number of ideas and theses concerning the hierarchical structure of the world or the phenomena populating the world. The basic idea of 'levels of organization' can be understood as a loose conjunction of the following elements: (a) (Part of) the world, or our representation of it, is structured into strata, where (b) each stratum comprises classes of structures or processes of relevant similarity, and (c) relationships within and between strata are based on some biologically relevant criteria (such as composition or scale).

Until recently, only sporadic attention has been paid to the precise character and significance of 'levels' as it is used in scientific contexts.[2] Though a number of philosophical accounts have already been offered concerning what levels *are* (Oppenheim & Putnam, 1958; Wimsatt, 1976, 2007; Craver, 2007, ch.5; 2015; Findlay & Thagard, 2012), much less has been said about the *significance* of the levels concept for scientific purposes. This paper will pursue this latter question. We offer here a descriptive account for understanding the usefulness of the levels concept in scientific usage. We propose that the concept of levels is used heuristically by scientists not so much to describe ontological matters as to specify some aspect(s) of the phenomenon in question as useful for a scientific question at hand. We contextualize this with a brief discussion of bounded rationality, and how the many meanings of 'levels' can be harnessed in different contexts to do various types of work.

We will begin by offering an orienting approach that shifts the focal point of analyzing levels away from their 'nature' to the significance it exhibits in scientific usage (section 2). This approach posits the levels concept as a heuristic, rather than principled, notion motivated towards structuring scientific problems. This approach is well positioned to deal with a nascent levels skepticism that seeks a wholesale dismissal of the concept in science and philosophy (Brooks, 2017). We then characterize two major ways that 'levels of organization' are heuristically applied in scientific work for problem-structuring purposes (section 3). The first pertains to its use as a descriptive term that captures the relevant details of interest in a system. The second pertains to the usage of levels as a key term within an embedding heuristic strategy for analyzing a biological phenomenon. 'Levels' works in both cases to impose structural assumptions on the system being investigated, to generate hypotheses regarding that system, or to mark interest or relevance of an aspect of the system that could or should be investigated to make progress on a research problem. These various applications, we continue, vindicate the usefulness of the levels concept by emphasizing more localized criteria of assessment, which do not rely on the idea first capturing 'deep' ontological content of the system it treats (section 4).

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[2] We refer to 'levels *of organization*' rather than other iterations of the 'levels' moniker (such as David Marr's "levels of analysis"). Though we will not argue for this point here, we feel that a number of 'levels *of x*' labels fall under the "*of organization*" qualifier as cognates or closely related derivatives; in particular levels "*of explanation*" and "*description*" often presume an underlying scaffolding afforded by 'levels of organization'.

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2. From the nature to the significance of 'levels'

Despite its prevalence, the concept of 'levels' has been getting a lot of negative attention recently (see, e.g., Potochnik & McGill, 2012; Thalos, 2013; Eronen, 2013; Levy, 2016). The crux of this skepticism is that 'levels' apparently comprises an inherently flawed concept whose significance for scientific practice has been highly exaggerated by philosophical partisans. This "levels skepticism" has multiple threads to it, roughly corresponding to which account of 'levels' one is entertaining (see Brooks, 2017 for more details). One thread, which focuses on comprehensive notions of the term like those similar to Oppenheim and Putnam (1958) "layer-cake" account, points out that the way that levels conceptualizes natural phenomena or interdisciplinary relations are simplistic or false. These and other problems are well-documented by Potochnik and McGill (2012). The more recent "mechanistic" account of 'levels' eschews the comprehensive spirit of the layer-cake model and opts for a contextualized understanding of the levels concept as designative of compositional relations within mechanisms. This account has been criticized as too narrow for a general understanding, because levels and interlevel relations do not easily generalize from given instances (DiFrisco, 2017; Eronen, 2013, 2015; Franklin-Hall forthcoming).

Regardless of the line pursued, 'levels' is consequently judged to be a flawed, and hence useless, concept that should be deemphasized or eliminated from the scientific lexicon. This dismissal rests on the premise that 'levels' fails to capture deep ontological content of the world. For instance, as generally construed, the levels concept is taken to posit a comprehensive ordering of the world into uniform, and wildly unrealistic, part-whole compositional relations, which in turn reduce the nuanced complexities of the world to mere caricature (see also Craver, 2007, p. 173). This, as Potochnik and McGill explain, identifies the problem with "the very notion" of levels itself, because "the uniformity of composition needed for stratified levels simply does not exist." (2012, 126). Correspondingly, Eronen (2013) lays out a "deflationary" approach to the more contextualized mechanistic account to the effect that other, more well-defined notions (such as composition and scale) can seamlessly replace mentions of mechanistic levels: "One outcome of analyzing levels in terms of scale and composition is that we no longer need any distinct notion of level, at least not in any sense resembling levels of mechanisms. If scale and composition are sufficient for analyzing explanations in neuroscience, the notion of 'level' [in the mechanistic sense] does not add anything to our conceptual tool kit" (2013, 1049).

In contrast to this skepticism, we offer an approach that turns this assessment on its head, and embraces the ambiguity of 'levels' as vital to the flexibility the concept exhibits in expressing many distinct ideas. With a few caveats, we find the skeptical charges to be inconsistent with the way that the concept is used in scientific literature. We also deny particularly the implication that a flawed or misleading concept must therefore be useless, regardless of other conclusions to the status of 'levels' in capturing realistic features of the systems it represents (Guttman, 1976; Potochnik & McGill, 2012). We believe that 'levels of organization' can be shown to be a useful resource that benefits scientific thinking.[3]

Our motivation for focusing on the role and significance of levels instead of trying to define their nature is based on prudence rather than principle, and relates to the state of the discussion surrounding the levels concept. For one thing, there is a lack of coordinated and enduring community attention to systematically analyzing the levels concept (Wimsatt 1994/2007, 203; cf. Kim, 2002, pp. 3–4). This has resulted in a proliferation of many possible things for the term to express, a feature long observed of 'levels' (Bunge, 1960, p. 396; Grene, 1969; Craver, 2015, p. 2). We do not intend to depreciate individual efforts at analyzing the levels concept, but rather to note that *despite* such efforts there has been little remedial effect on the rampant ambiguity that leads to confusion, misconstruals, and frustration in the way the concept is applied in philosophy. Additionally, most analyses of 'levels' tend to privilege only one, often framework-embedded, conception to evaluate the term's contributions to the scientific purposes (Brooks, 2017). Focusing on the 'nature' of levels would hence impose the assumption that any scientific value of the concept must be anchored or derivative upon *first* capturing deep ontological content of the things it represents (e.g., Zylstra, 1992, p. 116).[4]

3. A heuristic approach to levels

'Levels of organization' appears throughout the literature as a kind of 'fragmentary' conceptual tool that exhibits stark variation in its conceptual content across different instances of usage, while simultaneously exhibiting some stability in the way that it is used. By "fragmentary" we mean simply a kind of structured polysemy whereby the semantic variation can be captured by distinct elements of semantic content. To illustrate this, consider for instance Carl Craver's "3 defining questions" of levels (2015, 3), which include content detailing (i) the relata designated by each level, (ii) the interlevel relation holding between levels, and (iii) the intralevel relation holding within a given level. Each of these elements constitute distinct semantic content contributive toward the levels concept as expressed in a given instance. That is, most if not all instances of 'levels' will require fleshing out specifically what each of these elements means, and the particular content of these elements of meaning can vary between instances: The interlevel relation may refer to composition or scale, while the intralevel relation may refer to different projectible properties held by a class of similar constituents. This polysemy is balanced, firstly, in that the levels concept is usually capable of clarity and precision in given instances, perhaps after some reflective reconstruction. Another factor balancing this ambiguity is the overarching epistemic goal of applying the levels concept. As we have argued elsewhere, the most important unifying epistemic goal motivating the usage of levels is to *structure scientific problems*, roughly meaning that the usage of levels is geared toward making scientific problems amenable to investigation (Brooks unpublished manuscript). This approach emphasizes the contextual aspects of how different components of meaning comprising 'levels' are locally determined in usage (see also section 4). In a nutshell: scientists construct an operational definition of 'levels' based on localized, interest-relative criteria, and then apply this definition heuristically for the purpose of providing relevant structure to scientific problems. The uses we detail below can be seen as specific ways that 'levels' fulfill the particular tasks set for the concept by this contextually-determined epistemic goal.

Nancy Cartwright (2016) and Sophia Efstathiou (2015) offer a complementary approach to our notion of 'fragmentary' concepts.[5] Referring to Neurathian *Ballungen*, or roughly cluster concepts, it is imperative of such concepts that they be made precise in a given scientific context, so that the claims and inferences being derived from such concepts are effective. Cartwright refers to this as "precisification",

[3] The natural continuation of this argument would be to deny that 'levels' delivers false or misleading descriptions of nature and science. The basis for this would be to build off the usefulness of the levels concept, seen heuristically, and then to motivate the inference that the levels concept in some cases delivers depictions of nature and science that are accurate enough to support the uses for which levels are applied as reliable in the first place.

[4] This does not eschew the importance of the ontological nature of levels, but rather should help give more definite orientation to such approaches to understanding the concept. For now, we will argue there is ample motivation for our approach in that the levels concept has been already attributed many different functions by philosophers and scientists. That is, regardless of how one countenances 'levels', the term is already doing much work for scientists and philosophers in articulating and introducing their ideas.

[5] Thanks to an anonymous reviewer for pointing out this parallel.